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GRADUATION CORRECTIONS FOR FUNDAMENTAL OBSERVATIONS.

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FOR POPULAR ASTRONOMY.

In earlier numbers of this Journal, December 1903, and November 1904, an outline has been given of the methods employed in deriving the errors of the 10′ divisions of our Repsold Meridian Circle. The last of the two articles included an illustration of the process for continuing the measurement of the intermediate 2′ divisions, in case the whole circle were to be investigated down to the ultimate divisions. It also contained a suggestion for the measure of a limited number of divisions, which might be required in special work. This plan is to measure directly, by means of the microscopes of one circle, the length of the arc between the nearest 10′ division and the desired 2′ division.

For the fundamental work, now in progress, the measurement of the required divisions has been carried out in this manner. There are needed the corrections for 48 divisions, for the first part of the program. Naturally, about one setting out of six will fall upon a 10′ division, already measured; and there will also be some repetitions of the same setting, especially as the instrument is used in both positions, fixed circle East and West.

The Nadir divisions for the fixed circle had been previously measured; first by a special set, made in June 1896; and more recently by the measurement of the 2′ divisions of a complete degree, in October 1904, including thirty minutes each side the vertical position. These divisions will serve also for stars that culminate close to the zenith.

It is not necessary to measure more than 4′ from the 10′ divisions, in order to reach any 2′ division; and by setting the instrument so that the intermediate division is at the center of the field, the microscope micrometers are only used for two revolutions each side the center. In the method used here both the 2′ divisions, on the same side of the standard 10′ division, have

been measured, in each series. This is almost essential, in order to derive the proper value of the correction for Runs of microscopes, and for the discussion of the small systematic error of the screws. This last error is well exhibited in the process of measuring a degree, completely, when the microscope micrometers are used for five revolutions each side the center, a series including the 2′ divisions in an arc of 10′ in length.

There is also some practical economy in measuring upon the extra division, for while thirty-two readings are required for the measurement of a single division, in the present scheme, sixteen being made upon the standard; the addition of sixteen readings gives the measure of the additional division, with only half as much extra work. The work has been so distributed as to include twelve settings in each series, which are on the average an hour and a half in length. Eight repetitions of a series, usually observed on cloudy nights, give eight double measures of 24 divisions. It would require twelve hours to measure a complete degree by this method, about fifty per cent more than for the measurement of a degree by consecutive steps, with the same precision of measurement.

In reckoning the utility of the investigation of graduation error, we must take account of the cost, and of the value of the product; just as should be done in any scientific work, and just as one would do for a business proposition.

In regard to the result, it may be safely assumed that modern circles are so precisely graduated that the errors might be neglected, if no special accuracy was desired. But for high class work this assumption cannot be allowed. An investigation of the quality and character of the graduation errors will show how great a part of the error is periodic or systematic; and will indicate whether any improvement can be expected, by interpolating values for separate divisions, between those actually measured.

Taking the present circle as an illustration, the error of truly periodic character is small, and if corrections were to be made from the curve followed by this error, the total error would be very slightly diminished. There are however marked tendencies towards the accumulation of errors of similar size and sign, and the tabulation of the 10′ correction has shown that the total amount of error would be considerably diminished by interpolation between adjoining divisions. The results of the measurement of the 2′ divisions can be similarly tested.

Including 144 corrections, tabulated for this series of measures,

the average correction is ± 0″.30. The mean of the corrections to the 48 standard 10′ divisions is — 0″.01, the mean of 144 is — 0″.06, and the average residual from this last mean is ± 0″.29. Accordingly, the probable error of graduation may be adopted, from the above residuals, as ± 0″.24 for a single division.

When the adjoining errors are compared with each other, the average of 96 differences is ± 0″.20; or, treated as accidental, the probable error of this nature is ±0″.11, for a single division. This is less than half the total error, and ±0″.16 would be assumed to be the probable error remaining in interpolated values, between the measured 10′ division errors.

To indicate any systematic character in the graduation of the intermediate 2′ divisions, the differences of adjoining corrections have been combined in the following groups.

Diff.	No.	Mean	Av.
10′ — 8′	25	+0″.05	±0.21
8 — 6	25	+ .05	.20
4 — 2	23	— .04	.19
2 — 0	23	— .06	.23

The tabular corrections may also be compared to test the measures. Thus, combining the 4′ arcs and 2′ arcs separately, in groups of 48 each, we have the following differences, reckoned from the standard 10′ divisions.

4′ arcs, mean diff. + 0″.10 av. diff. ± 0.″19
2′ " " " +0 .06 " " ± 0. 20

The mean, + 0″.08, agrees with the mean of the adopted corrections for the 2′ divisions measured. And the average differences, for 4′ arcs and 2′ arcs, indicate that the Runs correction has been well determined. Some of these measures were made in each position of the instrument. The Runs correction, Circle East, is — 0″.14 for one revolution; and Circle West, + 0″.04; while for both sets of microscopes there is a periodic term of 0″.085 per revolution.

In estimating the value of the product of this investigation, the precision of the measures must next be considered. The probable errors can be determined with considerable accuracy in this method, since the individual measures are combined in groups, from which the residuals have been taken out for every measure. From 768 residuals, combined in 96 groups, the probable error of a final correction is ± 0″.055. But the error in the determination of the Runs correction, which is due to the actual graduation errors of the divisions used, must be considered. The probable error of a 2′ arc has been shown above to be ± 0″.16; and since twelve such arcs are included in each series, for the

determination of the Runs correction, the probable error of this last is $\pm$ 0″.046. And thus the combined error of the measure is $\pm$ 0″.07.

The error of the measurement of the 10′ corrections is less than $\pm$ 0″.06, and the probable error of the resulting corrections to the 2′ divisions is $\pm$ 0″.09.

In measuring the 2′ divisions of a full degree, by consecutive steps, the probable error of the result was found to be $\pm$ 0″.05; and as a much larger number of 2′ arcs are included in the determination of the Runs correction, the effect of error in this last is much smaller. Also, each 2′ division is measured from two consecutive 10′ divisions, and the final error of the adopted correction is less than $\pm$ 0″.07

The probable error of a circle reading, in the present series, is slightly less than $\pm$ 0″.15. This is larger than that of the earlier measures. The probable error of measure could be assumed to depend strictly upon this error of reading. And the error of one complete measure, in the methods employed here, is the same as the error of a single circle reading. When both circles were employed, each circle was read twice at each setting, either by one observer, or by two observers interchanging. If r is the probable error of a circle reading, then $\frac{r}{\sqrt{2}}$ is the error of the mean of two; and $\frac{r}{\sqrt{2}}\sqrt{2} = r$, is the error of the sum of the readings upon both circles, at each setting. As each series was observed forward and back, the error of the reading upon each division, for the sum of both circles, was $\frac{r}{\sqrt{2}}$; and as the final correction is derived from the difference of two such positions of the instrument, the error of the correction is $\frac{r}{\sqrt{2}}\sqrt{2} = r$.

In measuring the 2′ divisions, by the use of one circle, the error of the double reading of the circle is $\frac{r}{\sqrt{2}}$; and as the correction is derived from the difference of the readings upon two divisions, the error is $\frac{r}{\sqrt{2}}\sqrt{2} = r$.

In each successive step, the error of the measure of the adopted graduation corrections must be considered, as was done above in summing up for the 2′ divisions. The 45° divisions depend upon 86 separate measures. While flexure would enter into the

separate measures, it is eliminated in the mean. And while the errors of graduation of one circle are combined with those of the other in a single measure, the errors of each circle are eliminated in the mean of the determinations for the other. This holds true, as far as the measurement of the 3° arcs of both circles. And for the measurement, successively, of the 1° arcs, and the 10′ arcs of circle A, the corresponding divisions upon circle B were so strongly determined, that the effect of their errors is very small.

Thus the successive steps in the process would be affected nearly as follows; the number of individual measures being given, and the dependence upon the preceding measures being indicated simply by the increase, which must be computed according to the formulæ for the probable error.

a = p. e. 45°	Divisions	$= \frac{\pm r}{\sqrt{86}}$		±0″.02
b = p. e. 15°	"	$\frac{\pm r}{\sqrt{46}}$	increased by $\frac{a}{\sqrt{2}}$	± .03
c = p. e. 3°	"	$\frac{\pm r}{\sqrt{20}}$	" " $\frac{b}{\sqrt{2}}$	± .04
d = p. e. 1°	"	$\frac{\pm r}{\sqrt{10}}$	" " $\frac{c}{\sqrt{2}}$	± .05
e = p. e. 10′	"	$\frac{\pm r}{\sqrt{8}}$	" " $\frac{d}{\sqrt{2}}$	± .06
f = p. e. 2′	"	(consecutive) $\frac{\pm r}{\sqrt{7}}$	" " $\frac{e}{\sqrt{2}}$	± .07
g = p. e. 2′	"	(extra) $\frac{\pm r}{\sqrt{8}}$	" " e	± .09

The increase in the probable error, as the method progresses, is quite well marked, in the above tabulation; and the advantage of measuring the 2′ divisions consecutively, is shown in the relation of the last two values, f and g. Two sets of measures were made for the 1° arcs, in 1896 and 1905. The probable errors were rigorously derived for the series of 1°, 10′ and 2′ measures; and while the values thus obtained are slightly larger than given by the theoretical quantities above, the combination in a second approximation, in which all the readings in a series are utilized for the determination of each correction, reduces the final probable error below the computed values above.

We are now prepared to test the value of our product — the resulting corrections. We shall assume, as result of experience, that the accidental error in the observation of a star, due to circle reading, bisection, and refraction, is ± 0″.2.

The probable error of graduation, for the 2′ divisions, may be

assumed to be ± 0″.25. The error in the measure of graduation corrections does not exceed ± 0″.10 at the maximum. Without following out the computation, here, the following values can be derived from the data given above, the results showing the errors without the use of any graduation corrections, followed by those in which corrections have been applied. The values derived from the use of the movable circle, which is shifted to a new position for each observation, and for which graduation corrections have not been determined, are also included. For the present scheme of fundamental work here, the fixed circle is used in both positions, for every star, including circumpolar stars at both culminations; and the movable circle is also used at every observation, being shifted between successive determinations.

Fixed Circle in one position.				Movable Circle.
1	Observation uncorrected		± 0″.32	± 0″.32
1	"	corrected	± 0″.22	
2	"	"	0 .29	0 .22
2	"	"	0 .17	
4	"	"	0 .27	0 .16
4	"	"	0 .14	
16	"	"	0 .26	0 .08
16	"	"	0 .11	
Fixed Circle in two positions.				
2	Observations uncorrected		±0.22	
2	"	corrected	±0.16	
4	"	"	0.20	
4	"	"	0.12	
16	"	"	0.18	
16	"	"	0.09	

It is shown above that, for the large number of observations required in Fundamental work, the probable error can be reduced to one half, by the use of graduation corrections for the fixed circle. And the limit of minimum error is the error of measurement of the graduation corrections for two positions of the circle, or of four positions for a circumpolar star observed at both culminations. With the movable circle, the error diminishes as the number of observations is increased.

We have still to reckon the cost of our product.

The original investigation, down to 1° divisions, completed in 1896, required about 100 hours of microscope reading for two observers.

The later work, including the 10′ divisions, completed in 1905, required about 400 hours for two.

The total observing time was thus equivalent to 1000 hours for one man, and the computing has taken approximately the same time.

This class of work is tedious in the extreme, and three hours of

measurement per day is as much as one should undertake, if the quality of work is to be kept high. About 160,000 microscope readings have been made. The entire circle could be measured, down to the remaining 2′ divisions, by one observer, in less additional time than the equivalent of what has been thus far employed. About 700 hours would be required for the measurement. The 2′ divisions of the movable circle could also be measured, in about 1500 hours, since the 10′ divisions would need to be first investigated.

April 17, 1906. Lick Observatory.

CHAMBERLIN AND SALISBURY'S GEOLOGY.*

F. R. MOULTON.

FOR POPULAR ASTRONOMY.

The third and last volume of the Geology by Chamberlin and Salisbury has recently appeared from the press, and the work may now be considered in its entirety. However, the present remarks will be devoted largely to the first chapter of volume II.

The work is divided into two distinct parts. The first part is volume I which treats of the action of geological agents, such as the atmosphere, running water, snow and ice, the ocean, life, etc. After the reader has been made acquainted in this volume with geological processes and methods of interpretation, the second part gives in volumes II and III a systematic historical account of the development of the Earth. This plan of treatment makes it possible to subject most simply every theory presented to the severest criticism. The work is precisely the opposite of dogmatic, and the perfect candor with which rival theories and the objections to them are considered make it a model of the scientific method of discussion. The spirit of science should be one of absolute honesty in the use of the data available, and it is this spirit which makes it of such high moral value. In Geology, as in other sciences, there are very many places where there are uncertainties which could easily be concealed. But the authors of these volumes have with praiseworthy fairness laid all the facts and hypotheses before the reader, and he could not, if he would, escape from the elevating influences of these methods.

The subject of Geology is a very broad one. Practically all of

* HENRY HOLT & Co., Vol. I, *Processes and their Results*, 654 pages; Vol. II, *Earth History*, 692 pages; Vol. III, *Earth History*, 624 pages.

physical science and a considerable part of biological science are directly or indirectly involved in it. The volumes which we are considering present an immense panorama, and there is little redundant matter in them.

Starting with the origin of the Earth, they picture the successive stages in its evolution,—a nuclear stage, a possible atmosphereless stage, early vulcanism, deformations, the archeozoic era, the proterozoic era, the paleozoic era, etc., with the various subdivisions. A fairly satisfactory theory of such a vast evolution as this is a great triumph of the human mind, and the pursuit of it must have fired the imaginations of those who have contributed to it as the imaginations of those were fired who first sailed the Earth's unknown seas and explored its unknown lands. This esthetic element of science cannot fail to impress the reader of Chamberlin and Salisbury's Geology.

Every one is to some extent a philosopher. That is, he consciously or unconsciously builds for himself a conception of the whole universe with which he is acquainted, and every opinion he holds is placed on the background of this general conception. There is a distinct and important philosophic element in science. Every separate datum is understood on the background of general conceptions, and perhaps modifies the general conceptions. The authors of this Geology have admirably shown the relations of facts and theories throughout the three volumes. It would be difficult to point to another scientific work so strong in this respect.

It is clear that a correct theory as to the origin of the Earth is very important in the ambitious task which the geologist sets for himself. Up to the present time geologists have been accustomed to take the original Earth as furnished them by the cosmogony of astronomers, and to make their theories agree with that conception of its origin. But in the present work the cosmogonical theories of astronomers have been questioned, and others have been suggested in their place. The geologist has a perfect right to do this, especially if he finds reasons for doubting the theories of the astronomers, and the astronomer should welcome any assistance on what is really his most interesting and ultimate problem.

While the collaboration of the authors has been so thorough that it is impossible by any "higher criticism" of style to distinguish the authorship of the different parts, it is stated in a foot note that Professor Chamberlin is the author of the chapter on the origin of the Earth with which volume II begins. Notwith-

standing the high interest attaching to the new ideas introduced, they are scarcely more interesting than the chain of steps by which they were reached. It is difficult to determine where they started. Perhaps Professor Chamberlin's long studies on the slow evolution of the Earth, and of the possible great effects of feeble forces when long continued, prepared his imagination for the bold conceptions which were necessary; and perhaps his experience as an organizer and director while President of the University of Wisconsin prepared him for the superintendence of the campaign which the attack on such a problem necessitates. But the active and evident steps commenced soon after he began to devote his time entirely to research at the University of Chicago. He had long been recognized as one of the foremost glacial geologists of the world, and at this time he seriously undertook an examination of the causes of the glacial epochs. These studies led to a careful consideration of the nature and extent of the Earth's atmosphere throughout geological history, for it is a most important climatic factor.

Geologists have based their theories respecting the early evolution of the Earth upon the Laplacian nebular hypothesis. This has led them inevitably to the assumption that all the atmosphere and water which the Earth possesses, as well as enormous quantities of oxygen and water now locked up in chemical compounds and crystals respectively, were once part of an extensive gaseous envelope surrounding a hot nucleus. Chamberlin's examination showed that this condition was inconsistent with the kinetic theory of gases as applied to the escape of atmospheres by Stoney and others. Clearly an error in one of the two theories caused the great discrepancy. While it could not reasonably be supposed that the ordinary laws of gases hold in the excessively rare atmosphere of the upper regions, it seemed probable that the chief difficulty arose from the acceptance of the Laplacian nebular theory as a fundamental hypothesis. This conclusion was strengthened by the fact that geological evidence is decidedly against any theory which postulates that there was an enormous original atmosphere which has constantly diminished in mass and volume throughout geological history.

The apparent failure of the Laplacian theory of an original gaseous nebula when applied to the history of the Earth's atmosphere led to a critical examination of the hypothesis. This naturally involved many questions of considerable mathematical difficulty, and in this work particularly Chamberlin welcomed and invited cöoperation. As has so often been illustrated by

commercial enterprises, great undertakings can be carried out only by organization and cöoperation. As is now well known, the dynamical tests of the Laplacian nebular theory were uniformly adverse to it, and a number of them were of such a crucial nature that it could no longer be regarded as a satisfactory working hypothesis.

The strong skepticism as to the truth of the Laplacian theory led at once to attempts to formulate something more satisfactory. The meteoritic hypothesis was tried even before the dynamical tests of the Laplacian theory, as it seemed to avoid the difficulties arising from the escape of atmospheres. In it the vast gaseous mass of the nebular theory is replaced by a great swarm of meteors which hold the lighter elements in their interstices and in chemical combination. Darwin has shown that this theory is dynamically essentially like the nebular theory, for it only replaces the molecules by particles of appreciable size. Notwithstanding prolonged efforts to develop it into a satisfactory working hypothesis, Chamberlin was compelled to abandon it as giving but little hope of valuable results.

While the meteoritic hypothesis was being examined it was found that if a planet grew up by the impacts of independent meteors revolving in the same direction on a nucleus revolving around the Sun, the resultant mass would have a forward rotation. This fact was seized upon as being of prime importance, for the Laplacian Theory and all of its modifications failed to explain the direction of rotation of the planets. Indeed, accepting the conditions which must be assumed to have prevailed when rings were left off, it seems fairly certain the planets must rotate in the retrograde direction.

As has been stated, the meteoritic hypothesis failed to satisfy the conditions; but if the meteors were supposed to be revolving in one general direction the rotations of the planets could be explained. It must be kept in mind that the dynamical conditions in the two cases are fundamentally different. In the meteoritic hypothesis, as well as in the Laplacian nebular theory, the dimensions of the mass were supposed to have been maintained almost entirely by the mutual impacts of the separate small masses. On the other hand, in the case considered by Chamberlin the orbital motions of the meteors kept them from uniting at the center of the system. In the former hypotheses the mass must have been approximately spheroidal, and, as Darwin has shown, of nearly uniform density in concentric layers: but in this, which Chamberlin calls the Planetesimal Hypothesis because

every body moves like a little planet, the mass must have spread out in the form of a relatively thin disk, and may have had almost any degree of heterogeneity. In the old hypotheses there was always the idea of fluid pressure and hydrodynamical equilibrium; in the planetesimal hypothesis fluid pressure plays an insignificant rôle, and the equilibrium being due to kinetic conditions, there is no such thing as general shrinking with loss of heat. The two conceptions are dynamically opposite and they can be regarded as closely related only if one has failed to get a grasp of the essentials of one or both of them. Progress will be fastest if these distinctions are sharply drawn, and if the two types of hypotheses are systematically used to represent the two sorts of dynamical conditions.

The problem of finding a plausible original planetesimal condition directed attention to the spiral nebulas which Keeler showed a few years ago are many fold more numerous than all other kinds combined. Everything that is known about them supports the idea that they are in the planetesimal condition. Moreover, they appear to be quite unrelated to other types of nebulas, no connecting links having been found. Chamberlin has suggested that they may have been formed by tidal disruptions when two Suns passed near each other.

A preliminary discussion of the evolution of a spiral nebula into a planetary system is given in vol. II, pp. 38-81. It will not be possible to give any detailed account here of the great questions involved. The 43 pages used by Chamberlin were sufficient to give only a very condensed treatment of many phases of the subject. Referring the reader to them for details, we shall have to content ourselves here with stating that the planetesimal theory explains the facts that all the planets and planetoids revolve around the Sun in approximately the same plane and in the same direction, that the orbits are not highly elliptic, that the planets rotate in the forward direction, that they retain many of the lighter gases, that the Earth is a solid, and that the moment of momentum of the system largely belongs to the planets. Under it, the rapid revolution of Phobos and of the particles of the inner ring of Saturn, and the retrograde revolution of Saturn's ninth satellite do not cause difficulties.

It is not putting it too strongly to state that a new idea of the first importance has been introduced into cosmogony after the conceptions of Laplace have been followed almost servilely for one hundred years. Besides giving us hope of working out a satisfactory theory of the evolution of our system, the suggestion

of the possible origin of spiral nebulas brings into the light the dispersive tendencies which certainly prevail, and which may be more important than those tendencies to aggregation which have heretofore alone been recognized.

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EDWARD HEIS.

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For Popular Astronomy.

The centenary of the birth of a great astronomer naturally calls for some notice of the man and his work.

Edward Heis was born in Cologne, Germany, on February 18, 1806. He was the third son of George Frederick Heis, an apothecary whose fondness for physics and mineralogy was evidently inherited by his son. After having completed his course at the Friedrich-Wilhelm Gymnasium in his own city, Edward entered upon the study of mathematics in the high school at Bonn. At the early age of 21 he successfully passed the state examination pro facultate docendi and solved two difficult prize problems. The first related to the restoration of the book "De sectione determinata" by Apollonius, the other, proposed by the well known historian Niebuhr, concerned a solar eclipse referred to by Cicero (De republica I, 16) of which Ennius had said: Soli luna obstitit et nox. Young Heis showed that this eclipse occurred in the year 400 B. C., and that the Sun had set for Rome soon after the eclipse had begun, thus explaining the meaning of the cited expression.

Heis became professor of mathematics and physics at the Friedrich-Wilhelm Gymnasium in his own city of Cologne in 1827, and remained in this position for ten years. From 1837 to 1852 he taught mathematics, physics and chemistry at the combined Real-und Gewerbeschule at Aachen.

But astronomy was always his favorite science. His means however were very inadequate for its pursuit. His largest telescope was only a four-inch without a dome to cover it, and he never possessed a mounted meridian instrument, nor did he ever enjoy the help of an assistant. His observatory was most primitive, being nothing but a platform on the roof of the academy with a few rooms below it. Yet this great man possessed of a tireless energy and of an extraordinary keenness of

sight, made and discussed an enormous number of most valuable astronomical observations.

His astronomical activity began in the early forties when he became acquainted with Argelander, who had been called to Bonn to found an observatory. Being himself very much handicapped by the want of means, Argelander began the observation of variable stars according to the method to which his name has been attached, and which enables very valuable work to be done with small telescopes and even by the unaided eye. The great usefulness of Argelander's method soon became apparent in the now classical discussion of the light curve of β Lyrae (1844) by both astronomers. They continued steadily to observe this star and published a second paper on it in 1859. These early observations are of especial value just now, because the light curve of this star seems to have undergone essential changes during the last few decades.

Heis devoted many a night of his life to variable stars. His original observations of them, however with those of Adalbert Krüger, Argelander's son-in-law, were published only in 1903, a long time after his death, by Father Hagen of Georgetown College Observatory.

In 1849 Heis published a series of observations undertaken by himself and his students in Aachen on the periodic star showers. These observations became more extended after his removal to Münster in 1852, whither he was called at the suggestion of Alexander von Humboldt, to the third volume of whose Cosmos he had furnished many valuable contributions. As the University at Münster as late as the beginning of the seventies could count only about 400 students (a number tripled by this time) it was impossible to have more than one professor for both mathematics and astronomy. Heis occupied this position for more than 25 years, from 1852 until his death in 1877, and it was only during the last years of his life that a second professor of mathematics was appointed.

As teaching took up so much of his time, and as he was intensely interested in this work, he has sometimes been blamed for want of originality, an accusation to which his Collection of Examples and Exercises in General Arithmetic and Algebra (1837) is a sufficient refutation, since it is still very much in demand. The same is to be said of his three books on Plane and Solid Geometry and Trigonometry, which he elaborated with the help of Th. John Eschweiler. His mathematics teems with practical applications.

His inaugural publication at Münster was concerning the number and brightness of the stars. It was a fit preliminary to the great work of his life, the Atlas Coelestis Novus, which was published in 1872. In this monumental work Heis enumerates 5421 stars visible in central Europe, 2153 more than had appeared in the Uranometria Nova of Argelander in 1843. His keen eye could separate such close doubles as δ_1, δ_2, ϵ and 5 Lyrae, and he could count 11 stars in the Pleiades.

The Atlas is also a work of art. When it appeared, the representation of the usual figures of the constellations was still a very important question. Heis solved the problem by printing the stars and the reference lines in black, and the figures and boundary lines of the constellations in red upon a white background. In this way the historic figures, which are such an aid to the memory, received their due consideration without interferring with the scientific and accurate location of the stars in the heavens. The figures themselves Heis copied from the Farnese marble globe in the Bourbon Museum in Naples, thus going to the original Greeks for his models, and he has added many fresh details to them in the Atlas.

Surpassing Argelander's Uranometria Nova, its prototype, in the number of stars, Heis's Atlas Coelestis Novus is also superior to it in its representation of the Milky Way, which is entirely wanting in the Uranometria. While the older atlases drew the outlines of the Galaxy in sharp-cut lines, Heis gave it in its true form with five degrees of luminosity, the faintest of which extends almost to the Pole Star. His example has given the initiative to the three other delineations of the Milky Way which have followed his during the 19th century, that of the Belgian astronomer Houzeau which was made in the tropics and gives the Galaxy complete, that of the German Boediker made with Lord Rosse's telescope at Parsonstown in Ireland, and that of the Dutch astronomer Easton. While, of course, Heis's estimates of magnitudes do not descend to such fractions as are obtainable by modern instrumental photometric methods, his scale being only to thirds, (1, 1.2, 2.1, 2, 2.3, 3.2, 3, 3 4, 4.3, 4,) his Atlas will always remain a classic authority in these matters.

When Schiaparelli discovered that the orbits of certain meteor swarms were identical with those of certain comets, the material for the former was furnished him largely by Heis and his many students. Heis continued to observe the meteors until near the end of his life. His principal work on this subject, (1877) which embraces observations from the year 1837 until 1875, he did not

live to see in print, but fortunately the last pages could be secured from his manuscripts. This work gives 15000 paths observed by himself and his students of which 271 were seen in at least two places. It contains practical charts to facilitate the construction of the paths of the meteors, and has been surpassed only lately by the charts of Rohrbach. Heis also states the color, swiftness, character of trail, and other important matters. So valuable a work deserves more frequent study.

The zodiacal light which can ordinarily be seen only during certain months of the year after sunset or before sunrise when there is no Moon, was observed by Heis throughout the entire year, and on Christmas day he could see it both morning and evening. His observations upon it extend from 1847 to 1875. He has twice published charts for its study. The second chart (1877) gives also the boundaries of the Milky Way, in order to enable observers to distinguish it from the zodiacal light.

The five lines of work mentioned, the teaching of mathematics, the study of the brightness of the stars, of the Milky Way, of meteor swarms and of the zodiacal light, constituted the main life-work of Edward Heis. In addition to these he also observed the corona borealis, sun-spots, and sometimes made observations on the weather. In 1855 with Karsch, Michelis and Schellen he founded the periodical *Natur und Offenbarung* which is still in a flourishing condition. In 1858 he began a weekly paper on astronomy, meteorology and geography.

As he so well deserved, Heis received many tokens of appreciation. He was proud of his membership in the Royal Astronomical Society of England, the Leopoldina, and the Kaiserlich Leopoldinisch-Karolinische Gesellschaft der Naturforscher. He received diplomas from numerous scientific societies. The city of Münster named a street in his honor.

A sickness which he contracted after his trip to Italy in 1869 never left him, and he died of apoplexy on June 30, 1877.

In religion Heis was a devout Catholic. His life was very simple. He was rather reserved even with his best friends, and was always a kind teacher and an enthusiastic lover of nature. He was small of stature, and towards the end of his life somewhat corpulent. He had a very expressive countenance, and his bright clear eyes riveted every beholder. Edward Heis is a striking example of what may be accomplished by indomitable perseverance, even when handicapped by want of means and suitable instruments.

Omaha, Nebraska.

His inaugural publication at Münster was concerning the number and brightness of the stars. It was a fit preliminary to the great work of his life, the Atlas Coelestis Novus, which was published in 1872. In this monumental work Heis enumerates 5421 stars visible in central Europe, 2153 more than had appeared in the Uranometria Nova of Argelander in 1843. His keen eye could separate such close doubles as δ_1, δ_2, ϵ and 5 Lyrae, and he could count 11 stars in the Pleiades.

The Atlas is also a work of art. When it appeared, the representation of the usual figures of the constellations was still a very important question. Heis solved the problem by printing the stars and the reference lines in black, and the figures and boundary lines of the constellations in red upon a white background. In this way the historic figures, which are such an aid to the memory, received their due consideration without interferring with the scientific and accurate location of the stars in the heavens. The figures themselves Heis copied from the Farnese marble globe in the Bourbon Museum in Naples, thus going to the original Greeks for his models, and he has added many fresh details to them in the Atlas.

Surpassing Argelander's Uranometria Nova, its prototype, in the number of stars, Heis's Atlas Coelestis Novus is also superior to it in its representation of the Milky Way, which is entirely wanting in the Uranometria. While the older atlases drew the outlines of the Galaxy in sharp-cut lines, Heis gave it in its true form with five degrees of luminosity, the faintest of which extends almost to the Pole Star. His example has given the initiative to the three other delineations of the Milky Way which have followed his during the 19th century, that of the Belgian astronomer Houzeau which was made in the tropics and gives the Galaxy complete, that of the German Boediker made with Lord Rosse's telescope at Parsonstown in Ireland, and that of the Dutch astronomer Easton. While, of course, Heis's estimates of magnitudes do not descend to such fractions as are obtainable by modern instrumental photometric methods, his scale being only to thirds, (1, 1.2, 2.1, 2, 2.3, 3.2, 3, 3 4, 4.3, 4,) his Atlas will always remain a classic authority in these matters.

When Schiaparelli discovered that the orbits of certain meteor swarms were identical with those of certain comets, the material for the former was furnished him largely by Heis and his many students. Heis continued to observe the meteors until near the end of his life. His principal work on this subject, (1877) which embraces observations from the year 1837 until 1875, he did not

live to see in print, but fortunately the last pages could be secured from his manuscripts. This work gives 15000 paths observed by himself and his students of which 271 were seen in at least two places. It contains practical charts to facilitate the construction of the paths of the meteors, and has been surpassed only lately by the charts of Rohrbach. Heis also states the color, swiftness, character of trail, and other important matters. So valuable a work deserves more frequent study.

The zodiacal light which can ordinarily be seen only during certain months of the year after sunset or before sunrise when there is no Moon, was observed by Heis throughout the entire year, and on Christmas day he could see it both morning and evening. His observations upon it extend from 1847 to 1875. He has twice published charts for its study. The second chart (1877) gives also the boundaries of the Milky Way, in order to enable observers to distinguish it from the zodiacal light.

The five lines of work mentioned, the teaching of mathematics, the study of the brightness of the stars, of the Milky Way, of meteor swarms and of the zodiacal light, constituted the main life-work of Edward Heis. In addition to these he also observed the corona borealis, sun-spots, and sometimes made observations on the weather. In 1855 with Karsch, Michelis and Schellen he founded the periodical *Natur und Offenbarung* which is still in a flourishing condition. In 1858 he began a weekly paper on astronomy, meteorology and geography.

As he so well deserved, Heis received many tokens of appreciation. He was proud of his membership in the Royal Astronomical Society of England, the Leopoldina, and the Kaiserlich Leopoldinisch-Karolinische Gesellschaft der Naturforscher. He received diplomas from numerous scientific societies. The city of Műnster named a street in his honor.

A sickness which he contracted after his trip to Italy in 1869 never left him, and he died of apoplexy on June 30, 1877.

In religion Heis was a devout Catholic. His life was very simple. He was rather reserved even with his best friends, and was always a kind teacher and an enthusiastic lover of nature. He was small of stature, and towards the end of his life somewhat corpulent. He had a very expressive countenance, and his bright clear eyes riveted every beholder. Edward Heis is a striking example of what may be accomplished by indomitable perseverance, even when handicapped by want of means and suitable instruments.

Omaha, Nebraska.

THE USE OF THE SPECTROSCOPE.*

E. J. WALL.

The following notes are written with the hope that they may clearly define some of the very elementary facts connected with the spectroscope, an instrument which has lately come more prominently to the front in photographic circles. Being purely elementary, many statements must necessarily be made which, to the expert, will appear utterly trivial, and in some cases even misleading, because essential data for higher work are omitted. As, however, it is to the absolute beginner, the man who has never handled a spectroscope, that these articles are addressed in the hope that they may lead him to comprehend much of what now appears in the Journals on spectrography and to experiment for himself, the expert worker must pass such things by.

There is a well-known story to the effect that a candidate in an examination for physics defined a spectroscope as "a collection of bits of glass in a brass tube." This may or may not be a true description, as will be seen later; but I would rather define it as an instrument by means of which one can conveniently make and observe a spectrum. Now, a spectrum may be most familiarly described as a "rainbow." Every one has seen after a sudden rain-storm a brilliant arch across the sky, comprising practically red, orange, yellow, green, blue, and violet. This is a spectrum produced by the dispersion of the Sun's light by means of the drops of rain.

It is unnecessary to give a figure explaining what is meant by the "dispersion" of light. This is to be found in every elementary book on optics and many elementary books on photography, where one finds the familiar prism or triangular piece of glass, with the homogeneous beam of white light entering the same, and emerging therefrom split up into a rainbow or spectrum.

When we use one or more brass tubes or other opaque media so as to limit the light reaching the prism, we can obtain a spectrum which is unmixed with white light, which is not the case with the rainbow, and we at once see that the colors are extremely brilliant. If we use daylight, under certain conditions, or gaslight we shall find that the spectrum is a ribbon of colors, starting with deep red and gradually shading off into orange,

* *British Journal of Photography*, April 20, 1906.

this into yellow, and thence into green, greenish blue, bluish green, blue, bluish violet, into pure violet.

It will be noted here that there are two terms used, "greenish blue" and "bluish green," which require a little explanation, for such terms are very common. The rule is to denote the hue or tint of color when not pure by a compound term, the first word of which shall give the predominant color. Thus in the first case just cited, "greenish blue" means a mixture of green and blue, in which green predominates. Exactly in the same way we may talk of red-orange or an orange-red, the former having a preponderance of red and the latter a preponderance of orange, but both being orange.

Mapping the Spectrum.

If when we use a spectroscope we limit the white light falling on the prism to a very narrow slice or line, by means of what is technically called a "slit," we shall find on examining diffused daylight or sunlight that now our spectrum, instead of being a continuous and unbroken ribbon of colors, is broken up by innumerable transverse black lines, some fairly distinct and others extremely fine and faint. These lines are known as the Fraunhofer lines, although actually discovered by Wollaston in 1802; but it was Fraunhofer who set to work to map these lines out, and he discovered that two black lines in the solar spectrum corresponded with the two bright yellow lines given by burning sodium. It was by Kirchoff and Bunsen that the fundamental facts of the coincidence of the black lines in the spectrum of the Sun with terrestrial metals were established.

Fraunhofer designated some of the most striking lines by the first letters of the alphabet; and, reading from left to right, as in the usual way, we have A in the extreme red, B in the deep red, C in the reddish orange, D in the orange (or, as it is generally called, the yellow), E in the green, "little b" in the green, F in the green-blue, G in the deep blue, and H in the violet.

These lines are practically the only ones that we need trouble ourselves with, and they may be likened to milestones on the road, for they tell us exactly where we are. For instance, supposing we have either a diagram or a colored chart of the spectrum with these lines marked, and we are told that a certain plate is sensitive to D½E, we know that the plate is sensitive to violet and blue, and also to green and yellowish green. Precisely in the same way we know that when any one talks of a panchromatic plate sensitive to C¾D that it is sensitive to yellowish orange.

Another method of defining a particular part or color of the

spectrum is by naming the wave-length of the light. This may be done in three ways. Thus, taking what is known as the D line, we may express the length of the wave in thousandths of a millimeter, expressed by the Greek μ, and it would then be λ 0.58916 μ; or in millionths of a millimeter, expressed by $\mu\mu$ and it would be then λ 589.616 $\mu\mu$, or, more briefly λ 589; or we may write it as 6896.16 A.U. or t.m. A.U. stands for Angström Unit, and is named after Angström, who mapped and measured the visible spectrum from A to H. His map is usually called the Normal Solar spectrum, and was published in 1868. In making it, the unit was a ten-millionth of a millimeter, or t.m. For all photographic work the expression λ 589 is quite sufficient, for it will be seen later that for ordinary work the refinement of absolute measurements of wave-lengths to three or four places of decimals is absurd.

The Anatomy of a Spectroscope.

A spectroscope consists of three essential parts—the collimator, the dispersing medium (which may be either a prism or a grating), and the telescope, the last being for photographic work replaced by a camera.

The essential parts of the collimator are the slit, which admits a narrow beam of light, and a lens which merely makes this parallel before falling on the prism. Unfortunately, a slit made by an optician, and such a one as is necessary for the highest work, is somewhat costly, but it is by no means a difficult matter to make one which will answer very satisfactorily for photography. Brass is the easiest metal to use, and a printer's brass rule, about one-sixteenth of an inch thick, answers well. One edge must be bevelled off, first with a file and then on a stone, to a knife-edge; the brass should then be cut in two and the two bevelled edges placed together, with the bevel inside. The actual size of the slit depends upon the size of the lenses and prisms, and, roughly, the following will be correct: For a three-inch diameter lens, one-inch; for two-inch lens three-fourths of an inch; for one and one-half-inch, one-half-inch; and for a one-inch, three-eights of an inch.

One of the pieces of brass should be screwed or soldered on to a flat plate of brass, and the other left free, so that it can move in slides or grooves. It can either be actuated by a screw or it can be just shifted with the fingers. There is no necessity for this screw to be a micrometer, for a fine square-ended screw as used for electrical work answers perfectly.

The slit must be affixed to a brass tube, or, what is better for

photographic work, a wooden box, as this simplifies matters considerably. At the other end of the box should be affixed the lens, the diameter of which should be equal to the height of the prism, or half as much again. Ordinary landscape lenses can be used, without a diaphragm. The focus may be almost anything over seven inches, but ten inches or twelve inches is most convenient.

As already stated, the purpose of the collimating lens is to render the beam of light passing through the slit parallel, and therefore the latter must be at the equivalent focus of the lens. This may be found by opening the jaws of the slit as wide as possible, placing a small piece of ground glass across the same, and focussing a distant object on it. When the exact focus is once found the position of slit and lens may be fixed, otherwise one or the other should be adjustable, but there is no advantage in this, provided the adjustment is once made.

The prism should have an angle of 60 degrees, and such may be obtained at a very reasonable price made of flint glass, which is better than crown, as the dispersion is greater. It would be possible to use a hollow prism bottle filled with carbon bisulphide, but the practice cannot be recommended, because of the convection currents in it.

The prism must be supported on a stand opposite the center of the collimator lens, and with its side parallel to the slit. There is a particular position for the prism with respect to the lens, which is best to use. It is known as the angle of "minimum deviation," a term which will be explained later. The prism should be about one inch from the outside face of the lens.

The camera lens will be naturally that with which the operator is in the habit of working, and may be either landscape or a doublet. The length of the spectrum is dependent on the dispersion of the prism and the focus of lens. The lens should be placed about an inch from the prism face, and of course level with it.

When the whole apparatus has been set up the camera must be shifted towards the base of the prism till the spectrum is seen, because, as is well known a prism refracts as well as disperses the light, and the refraction is always towards its base. When the spectrum is seen centrally on the ground glass of the camera it may be focussed till its edges are sharp; we may then burn some salt in a bunsen burner in front of the slit and focus the bright yellow line.

We now come to the operation of setting the prism at the

angle of minimum deviation. This is most easily done with the salt and bunsen flame. The prism should be turned on its support first in one direction and then in the other, and the yellow line will be seen to move, and then it reaches a point at which it turns back again; this point where it begins to turn back shows that the prism is at the angle of minimum deviation. This is most easily done with the salt and bunsen flame. The prism should be turned on its support first in one direction and then in the other, and the yellow line will be seen to move, and then it reaches a point at which it turns back again; this point where it begins to turn back shows that the prism is at the angle of minimum deviation, and it is as well to draw pencil lines round the base of the prism on the support, so that the prism may always be set in the correct position. Instead of salt we may, of course, use magnesium ribbon, and find the minimum deviation for the bright green rays.

Provided the length of the spectrum is not too great, practically all the lines will be in focus at once, or an almost easier method is to see that the spectrum is the same width from the red to the violet. If it is not, the swing back or side swing must be used.

The above are the essentials for a prism spectroscope, with the exception of details as to the slit width; this will be dealt with later. There are however, serious objections to the use of the prism, and the apparatus is clumsy and takes up room, and unless the whole is firmly clamped together on a solid support there is great chance of parts shifting and of vibration. Much more compact and handier apparatus will be described hereafter.

THE NEED OF A REVIVAL OF INTEREST IN ASTRONOMY IN OUR SCHOOLS AND COLLEGES.*

JONATHAN T. RORER.

Previous to the adoption of the elective system Astronomy was studied in the senior or junior year of every good American college. In the year 1888-9, according to the report of the Commissioner of Education, out of forty-eight well-known colleges and universities, forty required Descriptive, or General Astronomy for the degree of B. A. In only eight institutions was it elective. A similar study today would reveal the opposite

* A paper read before the Camden Astronomical Society, April 11, 1906.

condition. It would be hard to find eight colleges or universities in America where astronomy is required for the bachelor's degree.

It is a matter of regret that no statistics are available that will show the number of students that are electing astronomy in the colleges. A few of the more prominent colleges and universities in New England and the Middle States, through their Professors of Astronomy, have kindly furnished me with this information. The reports that have come from these colleges, which include Harvard, Yale, Pennsylvania, Princeton, Brown, Columbia, Lafayette, Lehigh, and Haverford give an aggregate of 295 students who are electing elementary astronomy. (These figures do not include engineers taking astronomy in course.) This same group of colleges according to recent catalogues contain over 9700 students, not including their professional schools. From these figures it would appear that about three per cent of the students of these colleges are studying astronomy as a cultural subject. In the above group Harvard contributes more than half the students of astronomy. If we omit Harvard, the per cent of the remaining colleges falls to about two per cent of their registration. It is rather striking that this is the same percent that we find in the case of the public and private secondary schools as will appear later.

At Harvard, as is well-known, the laboratory method is accented in the elementary course. The leadership of Harvard in point of number of students of astronomy and in per cent of students, when compared with the other colleges in our group, points strongly to the success of the laboratory method of instruction.

Taking these colleges as a whole I believe that they are typical of existing conditions throughout the country so far as astronomy, is concerned; comparatively few students are electing the subject,—perhaps hardly more than are delving in Old Norse or Sanskrit, or Invertebrate Paleontology, to select a few courses from a current catalogue. Now is it right that astronomy with its historic background, with its great educational possibilities, should be relegated to the same ground as these minor courses of highly specialized science?

Let us look for a moment at the conditions in the secondary schools. Here, fortunately, we have more definite evidence. The excellent reports of the Commissioner of Education contain detailed statistics of the number of students that are pursuing each subject in the curriculum. I have gleaned a few interesting figures from the last report, 1903-04.

Total number of students in 8836 public and private high

schools and academies reporting to the Commissioner, 739,210. Number of schools teaching astronomy, 1,193, number of students of astronomy 14,205. Per cent of students of astronomy to the total enrolment, 1.92 per cent.

Ohio, Massachusetts, New York, and Pennsylvania each contribute over one thousand young astronomers. Is not Ohio's leadership with sixteen hundred students the fruit of the seed sown years ago by Mitchel? When we rank the states according to the per cent of students of astronomy to the secondary enrolment, Maine leads with 7.02 per cent, followed by West Virginia, Vermont, and Nevada. (Nevada reports but nine secondary schools of which one school has twenty-one astronomers.) New-Jersey has the twenty-first, and Pennsylvania the twenty-fourth place in such a list of states. Many interesting comparisons might be made from this table. We can fully appreciate the superior claim of New Mexico for individual statehood, rather than be joined with Arizona, when we note that the former has fourteen students of astronomy, while the latter has only two. Oh, how those matchless skies are being neglected!

But the statistics that are most impressive are those showing the gradual *decrease* in the per cent of astronomy students in the schools of the country. During a period of ten years, this per cent has decreased from 5.27 per cent in 1894-5 to 1.92 per cent in 1903-4. Astronomy has the least following of any of the secondary subjects. Psychology, Trigonometry, Greek and Geology are more popular in the order named. All of these subjects appear to be sharing the fate of extermination. If astronomy must be crowded out of the secondary curriculum, we would feel more resigned if her daughters Physics and Chemistry were flourishing. But the figures tell the sad story that during the same period these important sciences are year by year attracting fewer students. Which studies are thriving is asked? Algebra and Latin are waxing fat, each claiming the attention of about half the students, and both are increasing. Other popular studies are Rhetoric, English Literature, and History.

I cannot advance any claim of priority in noting this condition. From time to time articles have appeared from the pens of distinguished astronomers, from high school and college teachers, and from that broad and important class which we term friends of astronomy, noting this unfortunate tendency in our schools. It is of the utmost importance that all who love science and all who are interested in the best educational development should reflect on the causes that contribute to this decline of interest in astron-

omy and seek methods to correct it.

The elective system has entirely changed the field of educational competition. No longer is the battle between different institutions as it was a generation ago. Harvard, Yale, Princeton, Pennsylvania, all produce about the same type of culture, provided that we compare men who have elected similar courses. In education today the prophesy is fulfilled, "A man's foes are they of his own household." We may be slow to admit the warfare, the smokeless powder of educational casuistry has not revealed the guns of our enemies. In the university and college, under the plea that all subjects have equal educational value, department must compete with department and even course with course, each professor advertising his wares in the catalogue after the manner of merchants in the dailies. A similar condition confronts the high school. Some are now operating on the elective system and students can graduate from certain high schools in New York and Boston without a single lesson in mathematics. The elective system, the educational declaration of independence, has come to stay. It is useless to argue against it.

When there is but one hotel in a place, the bill of fare need not be a matter of great moment to the proprietor. But when competition arises, the cuisine becomes an important feature. Have not many teachers of science and particularly teachers of astronomy ignored the necessity and importance of properly presenting the truths of nature so as to attract students? We loathe the spirit of advertising, we cannot lower our standards to cater to the public. Our knowledge and observation of the abuses and low methods often resorted to in order to obtain publicity and favor, naturally arouse in us such antipathy that we are apt to go to the other extreme of hiding our light under a bushel. Astronomers more than any other class of men are the victims of this condition.

We may divide instruction is astronomy into three classes, distinct though not mutually independent: (1) Cultural Astronomy; (2) Practical Astronomy; (3) Theoretical or Professional Astronomy. The first concerns all men and of it I wish later to speak more at length. The second is recognized as a necessary adjunct of the equipment of the civil engineer and the navigator. As a necessity, it needs no fostering and is perhaps more nearly in a state of perfection than any other department of astronomy. The third and highest type of astronomical instruction aims to make investigators, or professional workers in the various departments of the science. This instruction is for the few whose

ability and natural endowments lead them to specialize in this vast field of research. The increased opportunities in our universities for work of this advanced character should be a source of pride to every lover of science. One hundred years ago, America had produced but two or three astronomers. Today she is taking a leading place in the astronomical advance of the world. If we are criticized as a commercial and materialistic people, we can at least comfort ourselves that we have a strong group of men whose one aim in life is the advancement of science and whose only recompence worthy of mention is the reward that comes to seekers after truth.

"Schools and universities," says Asaph Hall, "help forward knowledge by giving to many students opportunities to learn the present conditions, and from them some genius like Lagrange or Gauss may come forth to solve hard questions, and to break the paths for future progress. This is about all the schools can do."* There is another way that schools and colleges can help which the learned writer has not mentioned.

Investigation in science has become more and more expensive. Galileo discovered the four satellites of Jupiter with an inch glass; the new satellites required the costly equipment of the Lick Observatory. Photography and spectroscopy which occupy a large and ever widening field of work, are so expensive as to be prohibitive to the unaided individual investigator. Hence the necessity of endowments or funds by which instrumental equipment may be obtained and maintained in active work. Our schools and colleges must foster such an interest in astronomy that funds may be forthcoming spontaneously to meet the needs of American astronomers.

The late Mr. Yerkes acknowledged that the six inch telescope of the Central High School and the inspiration received from the revered Kendall were the early impulses that in later years made the Yerkes Observatory possible. Another pupil of the youthful Kendall, who entered upon his career as a teacher in the Philadelphia High School when only twenty years of age, was Professor George Davidson of the University of California, a man who has rendered distinguished services in the Pacific Coast Survey. It was Davidson who interested James Lick in astronomy, and when Lick was designing the monument that should perpetuate his name to coming generations, his friend, Professor Davidson, was successful in persuading him to estabish an observatory

* Proceedings, A. A. A. S., Vol. LII, p. 321.

rather than choose some more common but less worthy memorial.

Such instances, which might be multiplied in the history of science, show that we can impart a sense of scientific appreciation and awaken an interest in the development of science which may bear abundant fruit in future years. Therefore all who are earnestly striving to arouse an interest in astronomy, who are telling the people the story of the stars and the latest news from the worlds out on the frontier of space, should be encouraged,—whether they be teachers in our classrooms, or popular lecturers, or the authors of the "monthly heavens" which when they appear afford us delightful relief from athletics and politics when we take up our newspaper.

In conclusion, let me speak briefly of the factors that contribute to success in teaching descriptive, or cultural astronomy.

First, the text-book. To depend entirely on a text-book is the plan of least resistance but owing to the lack of well-equipped teachers, it is the method in most general use. Recent text-books are so suggestive and so much improved over the dry collections of facts that we called astronomies in years gone by, that even those whom necessity compels to cling closely to a book may be developed into appreciative students.

Second, the laboratory. For many years a few astronomers have been advocating laboratory methods for beginners, and the idea is being adopted in many schools and colleges all over the country. Part of this laboratory work can be done in-doors, but most of the exercises should be done out-of-doors. It may begin with the Sun,—shadows and their uses, the meridian, the Sun's diurnal path, rising and setting points; at night, the constellations can be studied, positions of the equator, the ecliptic, the equinoxes, etc.; the use of star maps and globes; the Moon's motion among the stars, the motion of Venus, Mars, Jupiter, and Saturn. Such simple observations require little or no apparatus. It is the sort of observing that the pupil can always repeat and enjoy in after life. Of course the telescope will be used as much as possible. This need not be a large one. The great difficulty about using expensive apparatus is that the student is introduced to a world which he may enjoy but the few minutes that he is using the instrument. When in later life this instrument is not in reach, his interest lags because it has not taken deep root in the fundamentals of the science. Large telescopes and the various instruments of the new astronomy are properly reserved for more advanced students.

There is one temptation that confronts all laboratory teachers

and overcomes many of them, the temptation to require too many metric exercises and an eagerness to secure too high a degree of numerical accuracy. Thus time is wasted and the student gets no more intellectual training than does the clerk from measuring yards of cloth or from weighing tons of coal. Weighing and measuring are merely incidents in laboratory work, not its end.

Third, the teacher. To secure the success that we need in science, the good text-book and the judiciously equipped laboratory must be supplemented by the enthusiastic teacher. It is a matter of nice discrimination to select observational exercises so as to be interesting and instructive and yet conserving the student's time; to select enough mathematical application to correlate and apply at least some of the student's knowledge, yet not so much as to discourage those not mathematically inclined; to keep the instruction abreast of the latest discoveries, yet not to introduce theory and technic beyond the comprehension of the student. The same careful judgment must weigh the amount of physics, chemistry, and physiography to be introduced.

With young students mythology can be introduced with fruitful effect. Many of these myths spring from facts and may be regarded as the science of those days when man was in the kindergarten of nature.

The history of science and the biography of its heroes should have an important place. When the principle of correlation is fully developed, this work will be shared by the teachers of English and History. Sir Isaac Newton is certainly as great a man as Cromwell or Milton and far greater than any of the Stuarts, and yet History clings so closely to statecraft and literature that our boys and girls are taught the life details of such personages while hardly the names of the great men of science are mentioned.

It is said that when Sylvester and Kronecker were trying to define mathematics, they got as far as to agree that "Mathematics is poetry." The meaning that I take from this is that mathematics and particularly the great physical sciences are like poetry rather than prose in that they express the deepest and most sublime truths of nature; they recognize the rhythm of nature's laws,—the complexity and yet the simplicity of her methods. Every ray of light is a rainbow; every rock is an ancient library whose books are always genuine; every star, a universe of cosmic evolution. The love of nature must be instilled, the joy of knowing her history and inner working, the pleasure of using the eye and ear to observe, the mind to discover hidden facts, and the lessons to be drawn from the self-sacrifice, the strength and

nobility of character of her children in all ages should not be neglected.

Astronomy should have a place in the liberal education of every one because it can bind together the elementary scientific training better than any other of the natural sciences. It engenders an abiding interest in science as a whole and an appreciation of the scientific method. To allow it to disappear from the high school will reduce the number of students in the college and university, and will deaden popular interest in pure scientific investigation, the disastrous effects of which would be hard to overestimate.

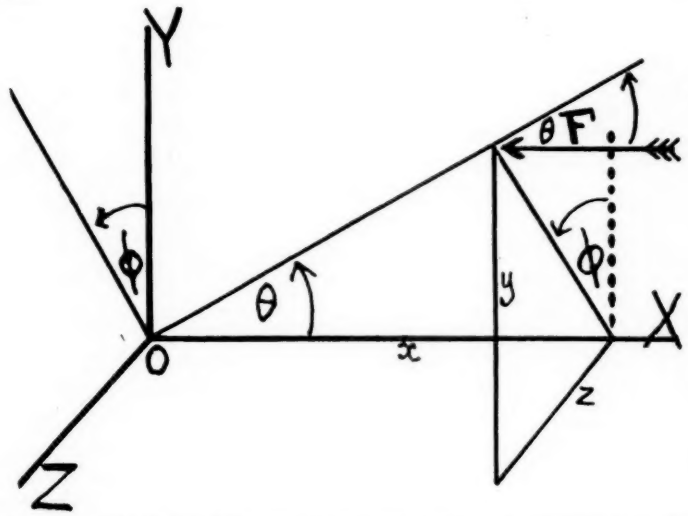
Central High School,
Philadelphia, April 11th, 1906.

THE EFFECT OF WIND FORCES ON AN OBSERVATORY DOME.

E. D. ROE, JR.

FOR POPULAR ASTRONOMY.

The following investigation of the effect of wind forces on an observatory dome was made by the writer in order to be able to cope as intelligently as possible with these forces in building a dome.



In the solution of the problem the dome is assumed to be a smooth hemispherical surface, and the normal component of the

wind pressure at any point is regarded as being the only effective force. The wind is assumed to be horizontal.

Let F denote the pressure of the wind per unit of surface perpendicular to the direction of the wind. Take the axis of x through O, the center of the dome, and parallel to the direction of the wind, the axis of y the vertical through O, and the axis of z perpendicular to the axes of x and y at O. Then at the point (x, y, z) of the dome the normal pressure p is equal to F cos θ, where θ is the angle from the axis of x to the radius vector r of the point (x, y, z), and the normal pressure on a small square at the point differs from $p\Delta S$, where $\Delta S = r^2 \sin\theta\Delta\theta\Delta\phi$, by an infinitesimal of higher order than the second, and where ϕ is the angle from the xy plane to the xr plane. If p_x, p_y, p_z be the resolved components of p parallel to the coördinate axes, the resultants X, Y, Z of all the forces parallel to the axes respectively will be

$$X = \text{Lim}\ \Sigma\, p_x\Delta S = 2Fr^2 \int_0^{\frac{\pi}{2}}\int_0^{\frac{\pi}{2}} \cos^2\theta \sin\theta\, d\theta\, d\phi = \tfrac{1}{3}.\ F\pi r^2.$$

$$Y = \text{Lim}\ \Sigma\, p_y\Delta S = 2Fr^2 \int_0^{\frac{\pi}{2}}\int_0^{\frac{\pi}{2}} \sin^2\theta \cos\phi\, d\theta\, d\phi = \tfrac{2}{3\pi}.\ F\pi r^2.$$

$$Z = \text{Lim}\ \Sigma\, p_z\Delta S = Fr^2 \int_0^{\frac{\pi}{2}}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin^2\theta \cos\theta \sin\phi\, d\theta\, d\phi = 0.$$

It will be seen that the horizontal force with which the dome is pushed in the direction of the wind is $\frac{1}{3}$ of what it would be if the whole quarter of the sphere acted upon were a plane surface perpendicular to the wind. Besides being pressed down by the force which has the value, the fraction $\frac{2}{3\pi}$ of the same force, the dome is compressed by equal lateral forces on either side (the two equal and opposite components of Z) of the value, the fraction $\frac{1}{3\pi}$ of the pressure $F\pi r^2$. R the resultant of all the forces makes with the horizontal (axis of x) an angle α, where $\tan\alpha = \frac{Y}{X} = \frac{2}{\pi}$. Hence $\alpha = 32^\circ\ 29'$.

We see that if the dome is strong enough to resist the compression, the whole strain comes on the rollers and track which should therefore be made strong enough for any strain that may be put upon them.

The assumption that the wind is horizontal is a fair one, as is also that of the smoothness of the dome. If the shutter were towards the wind, the inequalities of pressure arising would cause the dome to turn like a weather vane, (at least with a very

easily moving dome and a very high wind), and thus the spherical surface would be presented as we have assumed it.

Syracuse University.
19 April, 1906.

NEW YORK OBSERVATORY AND NAUTICAL MUSEUM.

W. W. PAYNE.

A most important movement in the interest of astronomy and kindred sciences is on foot in the city of New York.

It is apparently nothing less than the speedy erection and equipment of a great Observatory that will compare favorably with like institutions in other great cities in all parts of the world.

From the preliminary title that has been chosen for this new enterprise it is probable that nautical science will have a prominent place in the new scheme that is being planned now and worked out industriously. This feature may, and probably will be, a characteristic one, and no place for it could have been better chosen than in the great city of New York, the commercial metropolis of the western continent.

We notice with profound interest the names of the men who make the committee on preliminary organization. They are Frederick G. Bourne, Cornelius Vanderbilt, Edward S. Isham, George A. Cormack, J. D. Jerrold Kelley, and Charles Lane Poor. These gentlemen are well and widely known and will be a power, if we mistake not, in starting this noble enterprise. Charles Lane Poor is one of the most promising young astronomers of the present time. He is in the front rank enthusiastically grappling with some of the most delicate problems that are now occupying the attention of the professional and the practical astronomer. His recent work on the figure of the Sun is original, exact, and so comprehensive in method as to awaken very general interest in its preliminary stages. Whatever results follow from his critical studies of the figure of the Sun, we are sure that his work will have value for permanent records in solar investigations.

The preliminary plan and organization so far as known is that there shall be two distinct departments:

1. A Nautical Museum:

Where would be collected and exhibited models of all types of vessels, safety and signal devices, nautical instruments and methods of determining position, charts, marine engines and motors, and historic instruments and relics. The

museum and collections should be open to the public and should be arranged so that properly qualified persons could avail themselves of the facilities there offered for investigation and research.

2. An Astronomical Observatory.

Where would be made scientific investigations in the field of astronomy, navigation, and kindred subjects, and for this purpose the observatory should be provided with a complete outfit of astronomical and astrophysical instruments of large size. Certain portions of the observatory should be open to the public on two or three evenings per week.

Such a museum and observatory could be made a center of activity. It would supplement and add to the usefulness of many institutions and organizations now in the city. There are many institutions aud many persons having the facilities for collecting data, but unable to properly reduce and discuss such data. All material and data so collected could be sent to the museum, there to be worked up, put in shape, and made available for scientific use.

PRELIMINARY PLAN AND ORGANIZATION.

To establish such an institution worthy of the city of New York, it is proposed to form a corporation, chartered by the state, and to be known as "THE NEW YORK OBSERVATORY AND NAUTICAL MUSEUM." This corporation, which will be governed by a self-perpetuating Board of Trustees, will have an endowment, it is hoped, of not less than $500,000.00 and will purchase and own all the instruments, apparatus, and collections necessary to carry out the general plan. The income of the corporation, derived from endowment and from membership dues, wil be used for scientific work and for the advancement of the art and practice of navigation solely.

It is hoped that the city of New York will provide a site in Bronx Park and will furnish buildings for the museum and the observatory. If this be done, the corporation will open its collections to the public, and, under proper restrictions, will allow the use of its telescopes and apparatus for purposes of instruction.

This corporation will endeavor to secure the coöperation and support of the institutions of learning, of the various museums, and of other kindred organizations in the city by contracts of mutual aid and advantage. It is proposed to establish a Board of Scientific Advisers, consisting of the leading astronomers, nautical experts, and scientists in the country, who shall advise with the president, the Director, and the Trustees on all matters of general scientific policy.

MEMBERSHIP.

The corporation will establish various degrees of membership

by which citizens of New York, who may be interested in the general work of the Institution, or in some particular line of investigation, may become allied with it and contribute towards its support and the maintenance of its scientific reputation. In accordance with the custom prevailing in the various museums and similar institutions in this city, the following classes of membership will be established and appropriate privileges granted to each.

ANNUAL MEMBERS.

LIFE MEMBERS.

FELLOWS.

PATRONS.

BENEFACTORS.

Special arrangements will be made, whereby officers of the United States Navy, the Marine Corps, the Revenue Service, and the Mercantile Marine may become affiliated with and entitled to the privileges of the Museum during their active service.

BUILDINGS AND EQUIPMENT.

A principal building will be the *Nautical Museum*, wherein will be placed the collections of models, of nautical instruments, and of marine engines and motors. In this building will be included the executive offices, the library, the laboratories, workshops, and computing rooms. Adjacent to this central hall will be grouped the various buildings of the observatory, each instrument so far as practicable, having its own separate house.

The equipment of the observatory will be planned with special reference to the work proposed to be done therein. The New York Observatory must be prepared to take up problems not usually studied in other institutions and especially such astronomical problems as are related to navigation; the motions of the planets, the study of tides and tidal currents, the formation of special tables and aids to navigation; the rating of chronometers, the adjustment of compasses, and the scientific examination and study of nautical instruments and safety devices. Again, the observatory must have instruments, for student use and for popular instruction.

OTTO WILHELM STRUVE.*

M. NYRÉN.

Otto Wilhelm Struve was born in Dorpat May 7, 1819; his father Wilhelm Struve was then a professor in the University there and director of the observatory. Otto was the third of eighteen brothers and sisters. Of the parents, who had moved from Altona to Dorpat, the father came originally from Ditmarschen in Holstein; the mother, Emilie Wall, on both her father's and her mother's side came from French refugees: Valles (Germanized Wall) in Altona and Cuny† in Magdeburg. When Otto Struve graduated from the Academy in Dorpat at fifteen years of age he could not enter the University because he lacked one year of the prescribed age.

However, he was admitted to the lectures as a listener and so he was enabled to finish his University course at twenty years of age. Two years before this he had been appointed assistant in the observatory of his native town.

In the meantime the Astronomical Central Institute for Russia had been established in Pulkowa under the direction of W. Struve. Since Emperor Nicholas I with his usual munificence had opened to the director an unlimited credit for the construction and equipment of this institution, with this far-reaching confidence was united also the obligation to strive not only in the old paths of practical astronomy for good, yes, for better results than ever before, but new ideas could here be tried and put into execution, ideas to which W. Struve had been brought through many years of practice in observing, through a thorough knowledge of the astronomical instruments and through keen investigation.

There is no doubt that Otto Struve, who even as a boy must have often helped his father in the Dorpat Observatory, received from this activity of his father's in experiment and investigation a most lasting influence on his development, and that he was led in this way into practical astronomy. With what earnestness he devoted himself to this task of a life-time is evident from the fact that he worked for some time, a little later, in the mechanical workshop of Repsold, that he might also gain a

* Translated by Miss Isabella Watson, Carleton College, Northfield, Minnesota, from *Vierteljahresschrift der Astronomischen Gesellschaft*, 1905, Leipzic, Germany.

† Several illustrious men in Germany have come from the Cuny family, among others the former Prussian minister of public instruction, V. Gossler.

knowledge of instruments from the mechanician's standpoint. At the founding of the Pulkowa Observatory, of which W. Struve was appointed director, the special aim in view was the promotion of stellar astronomy. The instruments provided for this purpose were of a perfection never before attained; and these must now be given into the hands of prominent young scholars in order to secure the carrying out of the plan. With three colleagues, G. Fuss, G. Saber and C. A. F. Peters, O. Struve was also appointed as assistant to the director in 1839, from the very opening of the activity of the new institute. The 15-inch refractor was placed at his disposal; it was at that time and for several decades the most powerful optical instrument in the world.

Among the first conditions for a successful study in the realm of stellar astronomy are the most reliable constants possible for the reduction of the appointed observations; and now the question was to find out such constants, independent so far as feasible of determinations at other times. W. Struve had already derived the refraction from his observations in Dorpat; for his own task he took the aberration to be found from his observations with the instrument in the prime vertical; concerning the nutation Peters furnished his classical work "Numerus constans nutationis" and the numerical value of the same was to be even more surely established through a long series of observations in the prime vertical. O. Struve took the precession as his share. He acquitted himself of this task by his treatise "The Determination of the Constant of Precession with regard to the Proper Motion of the Solar System." In earlier determinations of the constants named, even in the most important, those of Bessel, the Sun's own motion was not taken into account, although it had been well-known for some time that this omission might influence the result under some circumstances. Bessel attempted to protect his result from this influence by the great number of stars used for the purpose and by their proportionate distribution, and for the most part he succeeded in doing so. With Struve the significantly smaller number of stars as well as the lack of a proportionate distribution of the same rendered such an allowance a necessity; but at the same time it gave as a secondary result a new determination for the apex of the Sun's motion. In spite of the very meagre material for such an investigation yet the certainty of this determination is clearly very strong as regards right ascension; but in declination, as the anthor himself explains, systematic errors of the catalogues referred to could

have produced a very considerable error in the value found.

On account of this treatise Struve was given the degree of Master of Astronomy by the University of St. Petersburg in 1841. A few years later, 1850, a gold medal was awarded him for it by the Royal Astronomical Society in London. For over half a century these three constants determined in Pulkowa have been universally used and have done much to bring astronomical observations as much as possible back to a common system.

Struve now undertook the principal problem of his scientific activity, and the great refractor was soon put exclusively at his disposal; this task was the searching for new double-stars and the most accurate possible micrometer measurements of these as well as of those already known. Through the classic work of his father, "Mensurae micrometricae stellarum duplicium," this branch of university study had been led into sure paths; it was for him now to lead it farther and to make more refined measurements. First by a thorough search of the northern heavens several hundred new double-stars were discovered thanks to the optical power of the instrument. Many of these belonged to the closer classes and so were of great interest to the observer since one must consider them as physically bound together. They were all carefully measured; those pairs which in the "Mensurae micr," plainly showed or allowed one to suspect a mutual change of position were collected for a special program of observations which, so far as possible, should be made each year. Even though the execution of this plan could not be strictly adhered to, and though the observations in general, so far as their number is concerned, have dragged far behind the original intention, still in the forty odd years of Struve's measurements we possess a material which has no equal in richness and homogeneity.

A half century ago but little attention had been paid to the differences in the measurements by various observers arising from physiological grounds. It was known that one could find systematic differences in star transits: differences had also been noted in the measurements of double-stars; this, however, was laid to the methods of observation used rather than to the observers. But the more carefully such measurements were carried out, so much the more urgent must appear the exact ascertainment of possible errors of a systematic character; still at the same time it was easier to ascertain them. In order to find out his own personal errors of measurement, Struve began

in 1853 very thorough observations on artificial double-stars, measurements which he repeated later, 1857, 1867 and 1876, so as to ascertain possible changes of his perception progressing with the years. In these observations he made use of a large board set up perpendicular to the visual line of the refractor at a distance of about 2.5 kilometers; this board was pierced with circular holes at different distances and in different directions from the center. These holes were all closed by stoppers of the same black color as the board itself, excepting always two, which must be carefully measured, and in which the black corks were replaced by circular ivory plates. Since the holes also had different sizes almost all combinations of distance and angle of position that can occur with different degrees of brightness could be measured by successive turnings of the board. Having an accurate knowledge of the distance of the board from the instrument, of the distance and direction of the separate holes in relation to each other, it was then possible to test the measured numbers as to their correctness.

In fact these measurements gave the result that the distances as well as the angle of position were affected by systematic errors of some importance which also changed with the angle between the plumb-line and the line uniting the object measured. At the same time the succession of observations made at different periods gave values so nearly the same that one is convinced that Struve's manner of observing did not change in the time from 1853-76. For the preceding years of observing, 1839-53, when no measurements on artifical double-stars had been instituted, very satisfactory corrections could be found through direct comparisons of the observations in the heavens carried on at this period with those made in late years.

With the help of the empirical formulas deduced from all these measurements the immediate results of observations were then corrected. But since the measurements reckoned according to previous formulas were already lying ready for printing, Struve published them as they were, and in a Supplement to Vol. IX of the "Observations" he gave the numbers corrected according to the definite formulas. These definitive values of the measurements were computed by Dubjago under Stuve's direction.

Thus it can justly be stated that Struve, in Volumes IX and X of the "Observations" containing the measurements of double-stars, has put into the hands of his professional colleagues a remarkably rich material elaborated with unusual care. Not simply the observations are given in this work; for a great

number of double-stars valuable comparisons are also given between the results of different observers, especially in cases where relative motions of the stars are indicated. These two volumes will for all time furnish an indispensable source of material for further research in this interesting branch of astronomy.

Besides the long series of measurements, which must be considered as Struve's principal work in the realm of pure science, he has also published separate results of his observations in a great number of monographs. These two relate mostly to double-stars, some to comets, to nebulæ, to star parallaxes, to planet satellites, to the rings of saturn, to a prime meridian etc. In the determination of the differences in longitude between Pulkowa and Greenwich by means of chronometer expeditions, Struve coöperated in both parts, the Pulkowa-Altona section in 1843 and the Altona-Greenwich section in 1844; and he published a detailed account concerning the last mentioned part. He united several important points within the Russian empire with Pulkowa in the same manner; for instance Moscow, Novgorod, Tula, Warsaw, Dorpat and others. He took part in two expeditions for observing a total eclipse of the Sun, in 1851 in Poland and in 1860 in Spain, and wrote out the results thus obtained. He also devoted some thorough study to an interesting historical episode which, though it does not concern astronomy itself, has to do with one of its greatest representatives: Kepler's relation to Wallenstein. He studied Kepler's manuscripts found in the Pulkowa library and wrote a complete memoir about it. Struve did a very spécial service for his science in giving out the catalogues of our valuable library up to the year 1880; the first part he published in 1860, the second together with E. Lindemann in 1880. A work in which Struve did much for practical astronomy is the revision and publication of the second catalogue by Weiss, including the stars of the zones of Bessel between + 15° and + 45° declination, and with this a very complete introduction. Another work of the same kind which cost him much time but also gave him much pleasure was done in collaboration with Schiaparelli; it consisted of two splendid volumes, the revision and publication of the double-star measurements, *Misure micrometriche* left by Baron Dembouski.

Struve's services were also claimed by other authorities in Russia. From 1848-62 he was advisory astronomer of the staff; from 1854-64 he performed a similar function for the marine and also had opportunity to have a hand in the geodetic and hydrographic work of these departments.

So we see Struve active in different branches of astronomy, everywhere advancing his science. The richest fruits of his work, the double-star measurements, are however reserved for the future.

All his life long he felt it a great sacrifice that circumstances so shaped themselves, that he, scarcely in the prime of life, must devote his time more and more to matters of administration instead of to his own researches.

When W. Struve moved from Dorpat to Pulkowa he brought with him a mass of valuable scientific material some purely astronomical, some geodetic, all of which needed systematic rearrangement. Here the geodetic problems were significantly increased until they embraced a hitherto unmeasured meridian arc of 25° 20′, from the Danube to the Arctic seas. This rich material he did not wish to intrust to strange hands but to work it over himself or to have the computing done under his immediate supervision. Since he was holding the position of director of the observatory and must represent it first of all before the public, his time was so taken up with all this that after a few years scarcely any time was left him for the inner regulations and matters of administration. In the account of his father's life O. Struve mentions the year 1845 as about the point of time after which W. Struve withdrew more and more from the management and confined himself almost exclusively to his own researches. In this way all the details of management, so small but consuming so much time, fell early to the lot of O. Struve, even before he had reached his thirtieth year. Consequently, a description of his career and of his activity from this time on until his death coincides in great measure with the history of the Pulkowa Observatory.

A few years later the position of assistant astronomer was created at the observatory and assigned to O. Struve. After the severe illness of his father in 1858 he was appointed manager of the observatory and after his father's final retirement he was made director in 1862. But a few years later he was visited by an illness so severe that his physicians as well as he himself considered his recovery as very improbable. On this account he desired even then to ask for his discharge. At the request of his friends a longer leave of absence was granted him instead and he spent it, a whole winter, in Italy. After a year he returned with restored health and strength and could enter again upon his official duties. He kept his position until the end of 1889 when he retired. He was elected as associate of the St. Petersburg Academy of Science in 1852 and in 1861 as a regular member. Aside

from that, he belonged to the Academy *eo ipso* as director of the observatory. At the same time that he retired from the observatory he withdrew also from the Academy.

The mission to which Struve had had to subordinate himself as his father's assistant, viz, to put his own researches in the second place and the common interest of the observatory in the first, he still kept constantly in view after the entire responsibility fell to his charge. As early as 1847, when he was making a visit of some length in Pulkowa, Airy expressed his regret that the observations were not printed and thus made available to astronomers in general, especially those made with the meridian instruments of whose unusual exactness one could be convinced by a few minor series that had been published. Of course the Pulkowa astronomers were also well aware of this drawback. But since it was not desired to publish a "rudis indigestaque moles," and since the working force was not sufficient for the necessary reductions, the observations up to this time had had to remain unpublished. About this time a beginning with the reductions was really made. But the current work of the observatory and still more the geodetic work, kept the few astronomers so occupied that the reductions just mentioned had to be again set aside. Not until ten years later through the joint urging of W. and O. Struve did they succeed in getting the working staff as well as the general condition of the observatory notably improved; and then the work on the reductions could begin in earnest.

First of all, the Fundamental Catalogue, planned from the beginning for 1845, must be prepared from the observations of Schweizer, Fuss, Lindhagen and Wagner with the transit instrument and from those of Peters with the vertical circle. Then in 1869 the first two volumes of the "Observations" could be published; these were prepared by Wagner and contained among other things the right ascension catalogue of the principal stars. Struve wrote a very full introduction for the first volume. A few years later followed the fourth and fifth volumes with the declination catalogue edited by Gyldén. Of these also the first volume had an introduction by Struve. In the meantime appeared the third volume, which contains Wagner's discussion of the right ascensions observed and of their preparation for the catalogue and also the observations in the prime vertical, edited by Döllen; the introduction was supplied by Struve. The observations begun on the meridian circle were now under Wagner's supervision, carried on by von Asten, Bruns and Dubjago and they

were finally brought together in a catalogue by Backlund. In the meantime Struve had started the original plan of his father, that of repeating at certain intervals the fundamental series of observations; the execution of this plan for the year 1865 was intrusted to Wagner at the transit instrument and Gyldén, later Nyrén, at the vertical circle. The results derived from this series by Wagner and Nyrén appeared in 1887 in a catalogue for use in common for both coördinates. The third series of fundamental observations, for 1885, was then already in progress and approaching completion. Wagner and Wittram were observers then and later Werner at the transit instrument and Nyrén at the vertical circle. The catalogues made from this third series were not completed until after Struve's departure.

During the time spoken of active work was being done also on the meridian circle, first by Winnecke, Gromaczki, Nyrén, V. Fuss, Kartazzi, but especially after the instrument was given over into Romberg's hands. The fruits of this work aside from the completion of the catalogue work above-mentioned are seen in the revision of the so-called additional stars in Romberg's catalogue of 5634 stars and in a large catalogue not yet published. Extensive series of observations were also made with the transit instrument in the prime vertical, by Oom from 1861-63 and by Nyrén from 1869-82, with interruptions. Report has already been made of the work carried on by Struve himself with the large refractor. During the period in question Hermann Struve began with the same instrument his observations which he continued on the thirty-inch refractor obtained later. We must not neglect to mention also, how Hasselberg at this same time was making his investigations in spectral analysis in spite of the imperfect apparatus with which he had to make shift for a long time.

Mention must also be made here of one other work which, indeed, was not completed by Pulkowa astronomers, but which nevertheless owes its origin to O. Struve: the "New Reduction of Bradley's Observations" by Auwers. Preparations for this undertaking had been made by Winnecke at Pulkowa in the early sixties. But after his illness the execution of this great work was again rendered doubtful until Struve succeeded in procuring for it the skill of Auwers already experienced in this line of work. The revision of Bradley's observations, a work standard probably for all time, which we now have in Auwer's three volumes, must be looked upon as the accomplishment of one of the greatest astronomical tasks which has been undertaken for

the advancement of stellar astronomy.

Of course it is understood that not all the works here mentioned are to be ascribed solely to Struve's credit, for the independent carrying out of their tasks even to the final conclusions was intrusted to the separate astronomers. But the power that held them all together was Struve, on whom one could always count as having an open ear for any deviations from the set program which might be found necessary, or for the starting of new undertakings. Without a well considered seizing of one opportunity, the letting alone of another, the separate forces would certainly not have striven with the same success toward a common goal. The youthful zeal with which Struve always attacked anything and which remained with him even to old age played a great rôle in it all.

Through Struve's personal acquaintance with nearly all contemporary astronomers he was always in a position to take an energetic part in undertakings desired or planned and of such extent that they could not be carried out without coöperation. Reference has already been made to a work executed at Pulkowa for the Astronomische Gesellschaft. He devoted much time and labor to the concerns of this society of which he was one of the founders; this he did especially in the years 1867-78 when he was the presiding officer. With what earnestness he took up the duties of this office is shown among other things in that he occasionally called together all the astronomers of the observatory in council over some important affairs of the Astronomical Society.

Struve took great pains with the preparations for observing the transit of Venus in 1874; ample means must be secured, new instruments provided and tested, several trips into foreign countries undertaken so as to make arrangements with other astronomers about the stations to be occupied; extensive trial observations must be made on models made for the purpose and finally several expeditions must be fitted out to different points in eastern Asia, in the Caucasus, in Persia, in Egypt. He also sent out expeditions from Pulkowa for observing local eclipses of the Sun, especially in 1887 when Russia offered the most favorable positions for observation; in these expeditions he took part himself and also aided to the best of his ability foreign expeditions which had come to Russia for the same purpose.

Several times also he instigated a wide circle of international observations of the occultation of stars during total eclipses of the Moon; Döllen had incited this for the determining of the parallax

and of the diameter of the Moon. As soon as it was known that photography could be used for astronomical purposes he took a lively interest in it, took part in the preliminary consultations about photographing the heavens, and was chairman of the first international congress convened for that purpose. As one of the representatives of Russia he also shared for a time in the international meter commission. From the very founding of the Royal Russian Geographical Society Struve was a member, and for a time as president of the section he conducted the works of its physico-mathematical department.

As may be known W. Struve had wished to add a worthy counterpart to his great work, the Russo-Scandinavian measuring of degrees of latitude; viz, a measuring of the degrees of longitude on the forty-seventh parallel between Brest and Astrachan. Since difficulties arose in the prosecution of this work in the states of western Europe, O. Struve was induced in 1860 to change his father's plan to this extent: that the arc should be measured on the fifty-second parallel instead of the forty-seventh, and indeed over a much longer distance, between Orsk in Siberia and Valencia in Ireland, stations which are more than sixty-nine degrees apart. This immense work, for which Struve used all his influence and his energy, was also accomplished by being shared in by all the countries through which the line runs.

The geodetic-topographic survey of the Great Russian Empire, which really belongs in the sphere of activity of the staff was zealously promoted by Struve; and this could be done especially through the course of study connected with the observatory, a course for officers who wish to perfect themselves as land-surveyors. Every larger expedition fitted up for such purposes had—and still has today—its beginning-and end-stations in Pulkowa. As representative of Russia, Struve has several times taken part in international geodetic congresses.

According to the plan of the founder, the astronomy of precision was to receive special attention in Pulkowa and hence only the apparatus necessary for that had been provided. Naturally also the astronomers belonged exclusively to the old school in which only this kind of practical astronomy was known. But as soon as the younger branch of the science, astrophysics, had shown through interesting results that it too could claim the rights of citizenship, Struve realized that the principal observatory of Russia could not neglect so promising a branch of astronomy even though the climatic conditions with us are very unfavorable

for it. So the necessary instruments for astrophysical research were immediately provided and negotiations were begun with the most prominent scholars in this line about a position in the observatory. Although the first attempts were not successful yet Struve did not let the matter drop. He appointed young astronomers who should perfect themselves in the new science, sent them to foreign lands for the completion of their studies, prevailed upon the government to create the position of an astrophysicist in the observatory, and after long years of effort he had the satisfaction of seeing complete activity in this branch begun in a beautiful laboratory built for the purpose.

Since the founding of the observatory technical skill had made great progress in the construction of optical instruments, and consequently the largest instrument at Pulkowa, the fifteen-inch refractor was no longer the greatest of its kind. But Russia's old prestige in this field must not be given up, and so Struve succeeded in procuring the large means necessary to place Pulkowa at the head of all such institutions as far as the optical power of the instruments was concerned. Immediately the work of constructing the new refractor was begun; several times Struve traveled to foreign lands on this business, twice even so far as America; in 1884 the new instrument finally stood ready for use in a massive tower.

After Kaiser Alexander III had undertaken in the following year an inspection of the observatory and especially of the powerful new instrument with its accompanying mechanism, by special order the emperor's thanks were communicated to Struve for the supervision and care which he had shown in the carrying out of all this work.

The scientific ends which Struve had in view first of all with this instrument were naturally of an astrometric nature: observations of faint and close double-stars, satellites of planets, nebulae etc.; but besides this the astrophysicist was to be able to turn the great optical tool to account for his purposes. The afterdays have shown as well in the one direction as in the other what a worthy acquisition the observatory made in this instrument.

While Struve was occupied in these ways for the development of Pulkowa his efforts were also of benefit to other astronomical institutions in Russia which kept up to the regulations of the principal observatory. This help naturally resulted from the fact that the greater part of our professors of astronomy in recent decades had gone out from the Pulkowa school and treas-

ured a warm friendship and deep respect for the director of the place of their first scientific activity. In this way the assistance was only a continuation and further development of old and cherished relations. The observatory in Taschkent, which is the best situated in Russia with respect to clearness of the heavens, owes even its origin to Struve's instigation. Through the many new furnishings and extensions during Struve's directorship he nearly doubled the creation of his father both in the way of instrumental equipment and as to the staff of fellow-workers. With every improvement the institution grew dearer to his heart. Since one can not expect professional knowledge from rulers, it was of great advantage to Struve in his transactions for the necessary and often very considerable supplies of money that he had influential acquaintances in all directions who could make the way easier for him. People had learned from experience never to question the expediency of propositions made by him, and the maintenance of Pulkowa's prestige could be emphasized in every instance with equally good success. Particularly did Struve have a powerful and kindly advocate in the lord high-admiral of of that time, the grand duke Constantin Nikolajewitsch, whose advice must find a hearing all the more readily since he himself commanded a not unimportant knowledge of astronomy.

Not only for the provision of new instruments could Struve control extensive powers; he also had a free hand in the question of the appointment of new co-laborers, a question laden with much greater responsibility. Undoubtedly it must be attributed to this circumstance not less than to the unerring insight in every matter affecting the good of the observatory, that he almost never had to regret any choice made.

Mention has already been made of Struve's efforts to unite geodetically the Empire of Russia with western Europe. Here is an example but little known of how he used his influence to the best advantage in another line, for a closer union between East and West in the question of calendar reform. Toward the close of the seventies in a conversation with Count D. Tolstoi, who was then minister of ecclesiastical affairs and also procurator of the holy synod, Struve succeeded in winning him over to his ideas on the calendar question. As a result he received from Tolstoi the commission to elaborate an opinion on the matter. Struve himself explained the astronomical grounds for the reform; that the councils of the oriental church had made no decrees which stood in the way of a change from the Julian to the Gregorian calendar, he left to professional scholars in that line to prove. Tolstoi

gave his full assent to this opinion and promised to bring the reform question up. In that case the reform of the Calendar would have been as good as decided, for at no time was any opposition made to Tolstoi's suggestions. But before the matter had gone so far as that, there came a new attempt on the life of Emperor Alexander II., the dynamite explosion in the subterranean passage of the winter palace; Tolstoi's power was crippled for a time, and the reform in question was postponed until some future time.

For those who held positions in the observatory Struve was a careful leader on whom they could always count to meet their wishes so far as possible. When it was found necessary to improve their material condition he succeeded, thanks to his energy, in obtaining the needed improvement much sooner than it could be accomplished for the teachers in the university. That no selfish interest urged him to these efforts is evident from the fact that he neither asked for nor received any advance for himself. He tried to the best of his ability to realize the principle inherited from his father, that all Pulkowa in its social aspect should represent to a certain extent one great family with the director's house as its center. One was always welcome in his hospitable house and at least one evening in the week all were expected there unless they were prevented on account of observing. An example will plainly show how pleasant was this unrestrained intercourse in our little colony and how highly it was prized. Since many of the workers spoke Russian either poorly or not at all the language of conversation in Pulkowa was at that time German. With the Russians, to be sure, Struve conversed in their own tongue although he had command of it only to a limited extent. In spite of the fact that these conditions were often somewhat inconvenient for families of Russian nationality, one can still hear them say today that, as far as social intercourse is concerned, they count the days spent in Pulkowa among the pleasantest they have known. In order to give visible expression to their respect for their director the observatory corps had an excellent portrait of him painted in 1887 for his jubilee after fifty years of service; the painting was done by the well-known artist Kramskoj and it has found a place in the gallery of the observatory.

Not alone for the Pulkowa astronomers was there ever a hospitable welcome in Struve's house. Many professional colleagues from outside—from Russia, from western Europe, from America have made longer or shorter visits there and have always been

joyfully received. Pulkowa always had an unusual power of attraction for the German scholars at St. Petersburg, who were nearly all connected with Dorpat. In the circle of his large family and his numerous relatives, several of whom had been brought up in his father's house like his own children, he lived like an honored patriarch, and all looked upon the Struve house in Pulkowa as their own home. Any deviation from this rule would have surprised all indeed, and not the least O. Struve himself.

It was said above that Struve's propositions in the most important instances never met with opposition. So it was also in the Academy, which has to select the officers of the observatory at the suggestion of the director and to propose them to the government for ratification. In 1887 for the first time he met with a decided refusal in a personal request. He felt so hurt by it that he at once gave evidence of his intention to resign. The request in question was in itself not important enough to give grounds for so important a decision; those on the opposing sides were doubtless well aware of this. The deep grievance which Struve felt in the refusing vote of the Academy came from his convictions that they wished to strike himself. Let that be as it may, the result was in any case, that he held himself aloof from the Academy henceforth and so gradually prepared his leave-taking. When Emperor Alexander III heard of it, well knowing how closely Struve felt himself associated with the observatory, he expressed the wish, when he met Struve, that he should remain at his post until after the fifty-year jubilee of the institution in August 1889; a wish that did honor alike to the Emperor and to his faithful servant. In accordance with this expression of the Emperor's will Struve remained in his position until the end of 1889, when he withdrew from the directorship of the observatory as well as from his membership in the Academy. He had then been connected with the observatory fully fifty years, twenty-eight of them as director; of the academy he had been a member thirty-eight years.

For some time after his resignation Struve worked in the interest of the observatory, for it was then that he finished Volume X of the "Observations," containing the remainder of his double-star measurements besides an index that goes with them. Also in the last decade he has been active in his science, so far as his powers, weakened through age, would permit; occasional little tasks and computations served him then more as a pastime. The above-mentioned complete biography of his father must be emphasized as a work of lasting worth done in this period. With great

interest he watched the progress of astronomy, as he had done before; and he kept up an active correspondence with many old colleagues until in the last years of his life his failing eyesight obliged him to limit himself in this also.

After his resignation Struve lived the first few years in St. Petersburg, aside from a transient residence in Switzerland and Italy; later, on account of his health he lived in foreign lands, mostly in Karlsruhe where he had near relatives. Yet in summer he often yielded to the longing for his old home, his children, grandchildren and great-grandchildren, and passed a few months in the neighborhood of St. Petersburg. On his last trip undertaken for this purpose he did not come further than Königsberg, where he was taken very ill at the home of his son Hermann, so that the journey to St. Petersburg had to be given up. The frequent visits which were made him during his summer sojourns near St Petersburg and occasionally in Karlsruhe by his former co-laborers and old friends always gave him very evident pleasure. Each time it revived in him a bit of Pulkowa and the old Pulkowa days. The beloved place of his fifty years of labor he saw for the last time eleven years ago. At the advanced age of almost 86 years Struve departed this life at Karlsruhe on the fourteenth of April of this present year 1905, without any very long illness. According to an order found in his will his mortal frame was burned in the crematory there. Unfortunately no member of the observatory staff could be present at the ceremony because of the news of his death being received too late. The deceased had often expressed the wish, also to the writer of these lines on the occasion of their last meeting, that he might find his last resting-place where he had spent the strength of his manhood and that too under the stone on which his instrument, the 15-inch refractor, had stood at the time of his observations. This wish will be carried out as soon as the formalities with the authorities are discharged. Otto Struve's ashes shall find the familiar road to Pulkowa; and in the little cemetary where his father rests they shall be buried beside his first wife. There the former pillar of the instrument shall mark the resting-place of its old master.

Struve was twice married, first to Emily Dyrssen, from the estimable family of a St. Petersburg merchant who also came from Holstein. A few years after her death in 1868 he married Emma Jankowsky from an officer's family in Livland; she too died three years before his death. In both marriages he was able to celebrate his silver wedding several years before the union was

broken. From the first marriage six children reached a mature age, four sons and two daughters, one of whom, however, died before her father; from the second marriage he leaves one daughter. Of the sons the two youngest are filling very important astronomical positions, as is well-known: Hermann, as professor in the University and director of the Royal Observatory at Berlin; and Ludwig occupying the same positions in Charkow. Of the older sons one serves in the ministry of the finances, the other is a geologist.

Struve was an amiable, benevolent man who attracted his acquaintances and held them by his profound mind. He had won an unusual number of friends through his active intercourse, both personal and by correspondence, with a very large number of people, among them also many who were not astronomers. With his decided personality one can not wonder that he also had some enemies. His learning was far-reaching even outside his own profession; he had an unusual tendency for humanistic studies and so great a knowledge of languages that those in his circle often declared that Otto Struve could also have been a philologist. Born a foreigner, it was only at twenty-four years of age that he, at the same time with his father, was made a Russian subject; yet he was always enthusiastic over the glory and the reputation of Russia; and the common conviction that this partizanship arose from pure sentiment often made the way to the goal easier for him. But this devotion to Russia did not lessen his love for the narrower home, the Baltic provinces; and especially Dorpat. His nature, his education and his mode of viewing things were thoroughly German and they remained unchanged. Especially in Dorpat did he see up to his old age the embodiment of all the good qualities of a German university; and when he met with an old fellow student, in spite of his gray hair one could believe him to be only a boy. One of the heaviest blows he ever met with was the news that the old honorable name of Dorpat was changed to Jurjew. He was heard to express his opinion about it in a voice trembling with deep sorrow.

A very notable number of marks of distinction fell to Struve's lot. Mention has already been made of the gold medal of the Royal Astronomical Society *. He was a member of nearly all great European academies of science and learned societies of that sort. In 1868 the Doctor honoris causa was conferred upon him

* It must be regarded as a fine succession of distinctions that three generations of Struves have won this high scientific recognition: Wilhelm Struve 1826, Otto Struve 1850, Hermann Struve 1903.

by the University of Bonn. The greater number of these marks of distinction, as well as the numerous home and foreign high orders which in the course of the years had heaped themselves upon him, he himself regarded from the standpoint that they were to be attributed more to his administration of the institution intrusted to him than to his purely scientific merits. What he accomplished in the one field or in the other we do not need of course to separate here: the honors in any case were intended for a man who had rendered much fruitful service in the cause of science and who had arrived at conspicuous results.

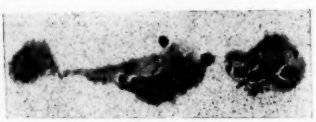
THE SUN-SPOT MAXIMUM OF 1905.

ROSE O'HALLORAN

FOR POPULAR ASTRONOMY.

The maximum of solar activity which is now on the decrease has shown observers of this generation how well marked the intensity may be, and how well founded is the recognized cycle of change. It may be some years early or late, have a divided maximum or one equally distributed, or the lull of minimum may be temporarily disturbed by an eruption of immense extent, but the fact of alternate increase and decrease continues just as evident as the cause of variation is hidden and elusive.

The maximum that culminated in 1892-3 was of average intensity and the minimum following was prolonged. A sun-spot of enormous size appeared in the beginning of October, 1903, and was succeeded by fifteen months of considerable activity though not more than about seven per cent of the spots attained medium dimensions. This moderate stage of maximum ended in January 1905 when a small spot that appeared on the tenth of the month



GREAT SUN-SPOT, JANUARY 16, 1905, 11:40 A. M.
Solar Prism.

developed into an elongated group 123,000 miles in length and 30,000 in width. The zones it occupied, about north heliographic latitude eleven degrees, were much disturbed during the preceding

month, but owing to a difference of longitude it could not be identified as a returned spot.

Ten umbræ were distributed over its three sections which, extending in a line, looked to the unaided vision like a black streak one-seventh of the Sun's diameter in length. Somewhat

GREAT SUN-SPOT JANUARY 30, 1905, 11 A. M.
Solar Prism.

decreased, it disappeared by rotation in due time, and five days afterwards on the 28th of January, 11 A. M. the foreshortened contour of another large eruption was a short distance inside the south limb. When central on the third and fourth of February its compact area was found to exceed that of the great disturbance of 1858 by an observer who measured the historic sunstorm of that year. This recent rival, being about 100,000 miles in length and 60 in width was visible to the naked eye for a week and disappeared at the west limb on the 10th of February. It was in south latitude fifteen degrees. On the 25th of that month a spot that resembled it in its declining aspect was inside the east limb in the same latitude. It may have been a delayed return, or, perhaps a later eruption in the adjacent rear tract. It was eighty thousand miles in length when near the center of the disk. On March the first a dark area evidently of unusual size was close inside the east limb. This was the fourth stupendous sunstorm within a period of seven weeks. The previous spot on the west side of the disk and this incoming leviathan on the east, formed a typical picture of this exceptional maximum. This fourth spot nearly equalled the second, but its cruciform outline shaded less of the surface. It was between eight and sixteen north latitude. Chiefly penumbral with numerous small umbræ, it was much decreased and scattered before reaching the west limb. Three months of moderate activity followed, and on the 25th of June a long faint dark streak was central a few degrees north of the equator. A development of a small group first seen on the 22d of the month, it was 96,000 miles in length and the chief umbra had cyclonic motion to the amount of 70

degrees. A group of nearly equal distinctness was in south latitude fifteen on the 9th of July. Two days after, one of larger proportions with several large umbræ was fully inside the north-east limb. Probably it was visible on the 10th which was cloudy here, and being within eight degrees of the Sun's equator completed its transit in about twenty-five days. The photospheric fragments or "bridges" in the lower umbra underwent rapid change even within a few hours as shown by the observations of Mr. M. H. Maw, F. R. A. S., London, July 15th, 4 P.M. local time;

GREAT SUN-SPOT JULY 15, 1905, NOON
Solar Prism.

of an observer in longitude 120 east from Gr. July 16th 8 A. M. local time; and those from which the accompanying illustration was made which happened to be four hours later than the former and four hours earlier than the latter. In a letter to the writer, Mr. Maw mentions that on re-examination the fragmentary bridge was found to be faintly recorded on the photographs of Greenwich Observatory July the 15th but as if submerged.

During the three months following, the surface again resumed the normal condition of spottedness in years of maximum. The eighth stupendous spot of the year then appeared and though not so compact as the great formation that crossed the disk between January 28th and February 10th, its scattered fragments gave it an extent of 135,000 miles east and west and 100,000 north and south. The mean latitude was about sixteen degrees north. Though sixty small umbræ were distributed near the edges, a vast clear tract of penumbra made its aspect distinctly grayish, while rapid change even in a few hours, was another of its characteristics. When still on the disk, there emerged inside the east limb an eruption in the same latitude but exactly the opposite in formation and tendencies. An encircling penumbra only 63,000 miles in length and more than half that in width enclosed centrally the largest undivided umbra that has appeared for some years. The stability of both umbra and penumbra during transit was remarkable.

In the beginning of November several spots came in on successive days, chiefly in the northern hemisphere, forming, on the 11th of the month, a stream that extended over three-fourths of the disk and included one division 50,000 miles in length.

These ten great sunstorms described, were distinctly visible to normal sight without magnifying power, while five of lesser size appeared that, in very clear weather, would be discernible to keen sight. In deducing general results for this year of extraordinary solar activity, the word "spot" is used to denote a discoloration whether single or in parts, provided the components are sufficiently near to indicate a common origin. As the largest eruptions are rarely spread beyond an area twenty degrees in diameter, a group scattered over that extent of surface is classed as one disturbance or spot. On 310 days when observations were obtained, the number of spots that came on the disk as seen with a four inch refractor, was 150, 70 being in the northern hemisphere, 63 in the southern, while of 17 the latitude was unknown.

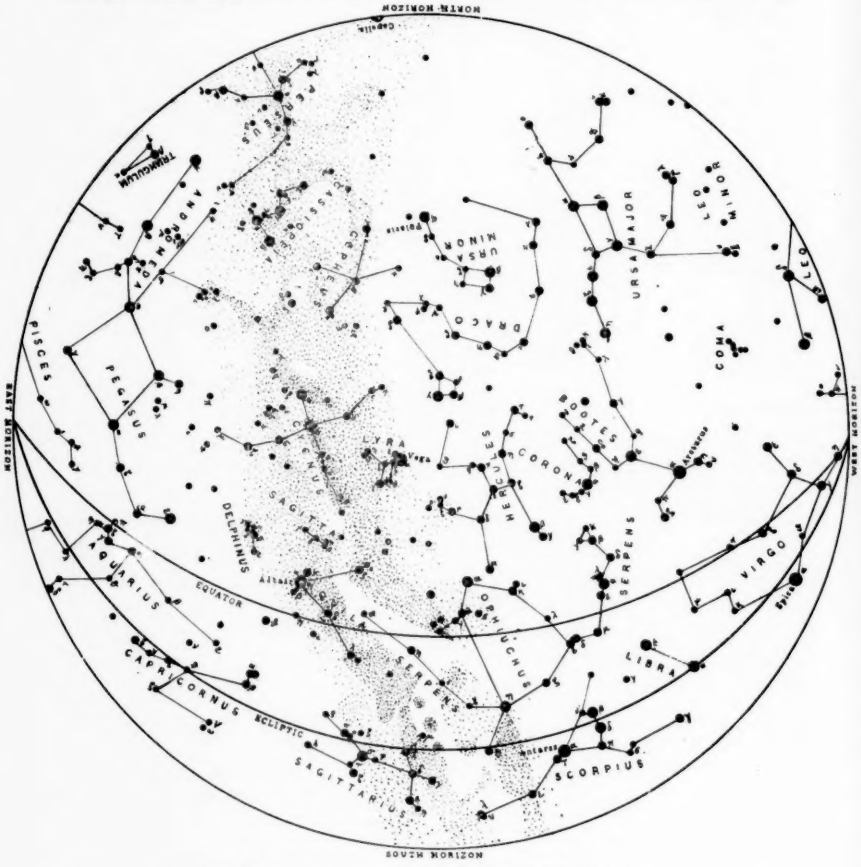
The coincidence of widespread magnetic disturbance at times of sun-spot maxima, and a corresponding decline as minima set in was frequently demonstrated during the nineteenth century, while repeatedly the aurora borealis glimmered overhead in seeming sympathy with the mysterious alliance. Many years ago, Lord Kelvin considered chance to be the invisible factor, but several great solar storms towards the end of the century with accompanying magnetic disaster gave added weight to the theory of connection, though magnetic storms sometimes occur when the Sun's surface is serenely white and enormous spots appear when electrical conditions are normal. It is a circumstance of much interest that, with one exception, neither auroras nor electrical phenomena were in notable coöperation with the transit of large spots during the recent maximum.

San Francisco, California.

PLANET NOTES FOR JULY AND AUGUST, 1906.

H. C. WILSON.

Mercury will be at greatest eastern elongation on July 15. The planet's distance from the Sun will then be 26° 39′, so that it should be visible as evening star for several days before and after that time. The brightness of the planet,



THE CONSTELLATIONS at 9 P. M., AUGUST 1, 1906.

however, is comparatively low at that time so that it will not be very conspicuous in the twilight. Mercury will be at aphelion July 22. In August Mercury will be at inferior conjunction on the 12th and at greatest western elongation on the 29th.

Venus during these two months will be well out from the solar glare and will be very conspicuous in the western sky in the evening. The brilliancy of this splendid planet is slowly increasing and by the middle of August will be nearly half as great as that at the maximum in October. The phase is gibbous, 0.8

of the diameter of the disk being illuminated on July 1, and 0.6 on September 1.

Mars will be in conjunction with the Sun July 15, and so will be invisible during the summer months.

Jupiter is morning star and too close to the Sun for observations of any value to be made.

Saturn is in the morning sky, in the constellation Aquarius, being near the meridian at $4^h\ 30^m$ A. M. July 1, and $2^h\ 30^m$ A. M. August 1, and at $12^h\ 15^m$ A. M. September 1. The inclination of the plane of Saturn's rings to our line of sight through them is now small, being only 3° 10′ on July 1, and 4° 40′ at the end o August, so that this summer is not a favorable one for the study of the rings.

Uranus is at opposition June 28 and so will be in best position for study for this year during the summer. The planet may be found with the aid of a good telescope in the constellation Sagittarius about two degrees northeast of the star λ. It may be easily distinguished from the neighboring stars by the size of its disk and its dull greenish hue.

Neptune is in conjunction with the Sun July 2 and so cannot be seen during the summer.

Occultations Visible at Washington.

Date 1906.	Star's Name	Magnitude.	IMMERSION. Washington M. T.	Angle f'm N pt.	EMERSION. Washington M.T.	Angle f'm N pt.	Duration.
			h m	°	h m	°	h m
July 1	ξ^1 Libræ	5.7	10 54	58	11 37	340	0 43
2	Bradley 1987	6.5	5 07	92	6 08	314	1 01
5	ξ^2 Sagittarii	3.7	8 22	125	9 22	247	1 00
5	π Sagittarii	3.0	14 47	115	15 43	227	0 56
7	21 Capricorni	6.5	8 53	29	9 28	320	0 35
8	*i* Aquarii	4.4	13 50	45	15 06	271	1 16
12	Lalande 2632	6.5	17 04	351	17 35	308	0 31
16	75 Tauri	5.2	13 16	43	14 01	287	0 45
16	Bradley 619	4.8	14 07	115	14 49	212	0 42
29	γ Libræ	4.1	11 18	89	12 18	294	1 00
Aug. 1	21 Sagittarii	5.0	5 07	28	5 26	351	0 19
1	B. A. C.6347	5.9	12 02	97	13 13	254	1 11
3	B.D.—18°, 5783	6.4	16 16	77	17 14	249	0 58
7	B. A. C. 81	6.3	18 24	48	19 32	259	1 08
10	μ Ceti	4.3	17 55	49	19 21	260	1 26
11	BD+12° 473	6.2	12 25	48	13 25	268	1 00
28	μ Sagittarii	4.0	8 46	126	9 50	235	1 04
28	15 Sagittarii	5.3	9 38	50	10 38	307	1 00
29	π Sagittarii	3.0	5 50	112	7 03	254	1 13
30	σ Capricorni	5.5	12 01	13	12 36	316	0 35

COMET NOTES.

Elements and Ephemeris of Comet *b* 1906.—In *A. N.* 4087 Mr. M. Ebell of Kiel, Germany, gives new elements of this comet, depending upon observations on the dates March 3, March 29 and April 24. The comet is very small and faint, and so can be observed only with large telescopes.

ELEMENTS.

$T = 1905$ Oct. 18.6620 Berlin
$\omega = 158° 42' 11''.4$
$\Omega = 342\ 13\ 35\ .1$ 1906.0
$i = 4\ 14\ 32\ .4$
$\log q = 0.522130$

Ephemeris of Comet *b* 1906.

Berlin Midnight 1906	R.A. h m s	Decl. ° ′	log *r*	log Δ	Br.
June 1	11 29 14	+1 11.8	0.5948	0.5558	0.42
3	30 14	1 04.8			
5	31 16	0 57.5	0.5969	0.5647	0.40
7	32 22	0 50.0			
9	33 29	0 42.2	0.5990	0.5734	0.38
11	34 39	0 34.2			
13	35 51	0 25.9	0.6012	0.5821	0.36
15	37 06	0 17.4			
17	38 23	+0 08.7	0.6034	0.5906	0.35
19	39 41	−0 00.2			
21	41 02	0 09.4	0.6055	0.5990	0.33
23	42 26	0 18.8			
25	43 50	0 28.4	0.6077	0.6072	0.32
27	45 17	0 38.2			
29	46 46	0 48.2	0.6099	0.6153	0.30
July 1	48 16	0 58.3			
3	49 48	1 08.7	0.6121	0.6232	0.29
5	51 22	1 19.2			
7	11 52 57	−1 29.9	0.6143	0.6310	0.27

VARIABLE STARS.

New Variable Star 33.1906 Aurigæ.—In *A. N.* 4087 Mr. A. Stanley Williams gives elements of a new variable in Auriga, which has a period of twelve days and which varies in brightness between magnitudes 7.2 and 8.1. The star is BD. + 390°, 1138 and its position is:

R.A. 1855	Decl. 1855	R.A. 1900	Decl. 1900
$4^h\ 51^m\ 22^s$	+39° 44′.4	$4^h\ 54^m\ 28^s$	+39° 48′.7

The light curve is very similar to that of S Aræ and Y Lyræ, the maximum being short and the rise being much steeper than the decline in the light curve.

Mr. Williams determines, from twenty-two photographs taken in the years 1900-1905 and visual observations on 29 nights between January 22 and March 12 of this year, the following elements:

$$\text{Max.} = \text{J.D. } 2415129.5 + 12^d.02\ \text{E} + 2.0 \sin (1°.8\ \text{E} + 70°).$$

Two New Variables 34, and 35.1906.—These are announced by Professor W. Ceraski in *A.N.* 4083 and were discovered by Mme. L. Ceraski on the Moscow photographs. Their positions are:

	R. A. 1855 h m s	Decl. 1855 ° ′	R. A. 1900 h m s	Decl. 1900 ° ′
34.1906 Camelopardalis	6 21 09	+64 10.3	6 25 31	+64 08.8
35.1906 Persei	3 42 01	+32 34.8	3 44 51	+32 43.2

The former, as indicated by eight photographs, varies between 9.7 and <12.5 magnitude. The latter on nine photographs ranges from 10.8 to <12.5 magnitude.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

(Alternate minima only are given this month.)

U Cephei

	d	h
July	1	4
	6	4
	11	3
	16	3
	21	3
	26	2
	31	2
Aug.	5	2
	10	1
	15	1
	20	1
	25	0
	30	0

Z Persei

	d	h
July	2	8
	8	11
	14	14
	20	16
	26	9
Aug.	1	22
	8	01
	14	03
	20	06
	26	9

Algol

	d	h
July	3	15
	9	09
	15	2
	20	20
	26	14
Aug.	1	7
	7	1
	12	19
	18	12
	24	5
	29	23

RT Persei

	d	h
July	1	15
	3	7
	5	0
	7	13
	9	6
	10	23
	12	16
	14	8
	16	1
	17	18
	19	11
	21	3
	22	20
	24	13
	26	6
	27	23
	29	15
	31	8
Aug.	2	1

RT Persei

	d	h
Aug.	8	16
	3	18
	5	10
	7	3
	8	20
	10	13
	12	5
	13	22
	15	15
	17	8
	19	1
	20	17
	22	10
	24	3
	25	20
	27	12
	29	5
	30	22

λ Tauri

	d	h
July	3	17
	11	15
	19	12
	27	10
Aug.	4	8
	12	6
	20	3
	28	1

Y Camelop.

	d	h
July	1	23
	8	13
	15	4
	21	19
	28	9
Aug.	4	0
	10	15
	17	5
	23	20
	30	10

W Urs. Maj.

July 1-Aug. 14 17h

Aug. 15-31 18h

Z Draconis

	d	h
July	1	16
	4	9
	7	2
	9	19
	12	13
	15	6
	17	23
	20	15
	23	8
	26	2
	28	20
	31	13

Z Draconis

	d	h
Aug.	3	6
	5	23
	11	9
	14	3
	16	20
	19	13
	22	6
	24	23
	27	16
	30	10

δ Libræ

	d	h
July	2	17
	7	9
	14	8
	19	0
	23	16
	28	7
Aug.	1	23
	6	15
	11	7
	15	22
	20	14
	25	6
	29	21

U Coronæ

	d	h
July	1	12
	8	10
	15	8
	22	6
	29	3
Aug.	5	1
	11	23
	18	20
	25	18

R Aræ

	d	h
July	5	4
	14	0
	22	21
	31	17
Aug.	9	14
	18	10
	27	6

U Ophiuchi

	d	h
July	1	13
	3	5
	4	21
	6	13
	8	6
	9	22
	11	14
	13	6
	14	23

U Ophiuchi

	d	h
July	16	15
	18	7
	19	23
	21	16
	23	8
	25	0
	26	17
	28	9
	30	1
	31	17
Aug.	2	10
	4	2
	5	18
	7	10
	9	3
	10	19
	12	11
	14	3
	15	20
	17	12
	19	4
	20	20
	22	13
	24	5
	25	21
	27	13
	29	6
	30	22

Z Herculis

	d	h
July	2	13
	6	13
	10	13
	14	12
	18	12
	22	12
	26	12
	30	12
Aug.	4	12
	3	12
	7	11
	11	11
	15	11
	19	11
	23	11
	27	11
	31	10

RS Sagittarii

	d	h
July	3	7
	8	3
	12	23
	17	19
	22	25
	27	11
Aug.	1	7
	6	3
	10	23

RS Sagittarii

	d	h
Aug.	15	19
	20	15
	25	11
	30	7

V Serpentis

	d	h
July	1	3
	8	1
	14	23
	21	20
	28	18
Aug.	4	16
	11	14
	18	11
	25	9

RX Herculis

	d	h
July	1	14
	3	9
	5	3
	6	22
	8	17
	10	11
	12	6
	14	1
	15	19
	17	14
	19	9
	21	3
	22	22
	24	17
	26	11
	28	6
	30	1
	31	19
Aug.	2	14
	4	9
	6	4
	7	22
	9	17
	11	12
	13	6
	15	1
	16	20
	18	14
	20	9
	22	4
	23	22
	25	17
	27	12
	29	6
	31	1

RR Draconis

	d	h
July	2	17
	8	9
	14	1
	19	17
	25	9

Minima of Variable Stars of the Algol Type.—Continued.

RR Draconis

	d	h
July	31	1
Aug.	5	17
	11	9
	17	1
	22	16
	28	8

RV Lyræ

	d	h
July	4	12
	11	17
	18	21
	26	2
Aug.	2	7
	9	10
	16	15
	23	20
	31	1

U Sagittæ

	d	h
July	2	3
	8	21
	15	16
	22	10
	29	4
Aug.	4	22

U Sagittæ

	d	h
Aug.	11	17
	18	11
	25	5
	31	23

SY Cygni

	d	h
July	3	14
	15	14
	27	14
Aug.	8	15
	20	15

WW Cygni

	d	h
July	4	2
	10	17
	17	8
	24	0
	30	15
Aug.	6	6
	12	21
	19	3
	26	4

SW Cygni

	d	h
July	1	14
	10	18
	19	21

SW Cygni

	d	h
July	29	1
Aug.	7	4
	16	8
	25	11

VW Cygni

	d	h
July	2	0
	18	20
Aug.	4	17
	21	14

UW Cygni

	d	h
July	3	8
	10	6
	17	3
	24	1
	30	22
Aug.	6	20
	13	18
	20	15
	27	13

W Delphini

	d	h
July	3	6
	12	21
	22	12
Aug.	1	2

W Delphini

	d	h
Aug.	10	17
	20	8
	29	23

Y Cygni

	d	h
July	1	17
	3	4
	7	17
	9	4
	13	17
	15	4
	19	17
	21	4
	25	17
	27	4
Aug.	3	16
	5	3
	9	16
	11	3
	15	16
	17	3
	21	16
	23	3
	27	16
	29	3

VV Cygni

	d	h
July	1	4
	4	3
	7	2
	10	1
	13	0
	15	23
	18	21
	21	20
	24	19
	27	18
	30	17
Aug.	2	16
	5	15
	8	14
	11	13
	14	12
	17	10
	20	9
	23	8
	26	7
	29	6

UZ Cygni

	d	h
July	10	19
Aug.	11	2

Maxima of Variable Stars of Short Period not of the Algol Type.

The times of maxima only are given; the times of minima may be obtained by subtracting the interval printed in parentheses under the name of the star.

Y Aurigæ

	d	h
	(−0	18)
July	3	19
	11	13
	19	6
	26	23
Aug.	3	16
	11	10
	19	3
	26	20

T Monocerotis

	d	h
	(−7	23)
July	21	3
Aug.	17	4

W Geminorum

	d	h
	(−2	16)
July	8	14
	24	2
Aug.	8	14
	24	1

ζ Geminorum

	d	h
	(−5	0)
July	11	1
	31	8
Aug.	20	16

S Muscæ

	d	h
	(−3	11)
July	3	13
	22	11
Aug.	10	19
	30	2

T Crucis

	d	h
	(−2	1)
July	6	1
	19	12
Aug.	2	0
	15	11
	28	22

R Crucis

	d	h
	(−1	9)
July	6	2
	17	18
	29	10
Aug.	10	1
	21	17

S Crucis

	d	h
	(−1	12)
July	3	8
	12	17
	22	2
	31	11
Aug.	9	20

S Crucis

	d	h
	(−1	12)
Aug.	19	5
	28	14

W Virginis

	d	h
	(−8	4)
July	13	23
Aug.	17	12

V Centauri

	d	h
	(−1	12)
July	1	10
	12	9
	23	9
Aug.	3	9
	14	9
	25	8

R Triang. Austr.

	d	h
	(−1	10)
July	2	7
	9	2
	15	20
	22	15
	29	10
Aug.	5	4
	11	23
	18	18
	25	12

S Triang. Austr.

	d	h
	(−6	0)
July	2	14
	15	5
	27	21
Aug.	9	12
	22	4

S Normæ

	d	h
	(−4	9)
July	7	7
	26	19
Aug.	15	8

R V Scorpii

	d	h
	(−1	10)
July	4	9
	16	12
	28	15
Aug.	9	18
	21	21
Sept.	3	0

X Sagittarii

	d	h
	(−2	21)
July	4	22
	18	22
Aug.	1	23
	15	23
	30	0

Y Ophiuchi

	d	h
	(−6	5)
July	16	16
Aug.	19	22

W Sagittarii

	d	h
	(−3	0)
July	1	3
	16	7
	31	12
Aug.	16	16
	30	21

Y Sagittarii

	d	h
	(−2	2)
July	5	15
	17	4
	28	17
Aug.	9	6
	15	1
	26	14

U Sagittarii

	d	h
	(−3	0)
July	4	23
	18	11
	31	23
Aug.	14	10
	27	22

Maxima of Variable Stars of Short Period not of the Algol Type.

(Continued)

β Lyræ		U Vulpeculæ		S Sagittæ		WZ Cygni Minimum		WZ Cygni Minimum	
d	h	d	h	d	h	d	h	d	h
−3	2	Aug. 24	6	(−3	10)			Aug. 24	10
+3	9	9	5	July 24	22	July 8	16	26	18
July 3	19	25	4	Aug. 10	17	11	0	29	2
16	17	SU Cygni		27	11	13	8	31	10
29	16	(−1	8)	X Cygni		15	16	TX Cygni	
Aug. 11	13	July 2	20	(−6	19)	18	0	(−5	3)
21	12	10	13	July 8	12	20	8	July 4	8
κ Pavonis		18	5	Aug. 10	7	22	16	Aug. 2	19
(−4	7)	25	22	T Vulpeculae		25	0	Sept. 1	6
July 1	6	Aug. 2	15	(−1	10)	27	8	VY Cygni	
19	11	10	7	July 2	6	29	17	(−2	2)
Aug. 6	15	18	0	11	3	Aug. 1	1	July 8	4
24	19	25	16	20	0	3	9	23	21
U Aquilæ		η Aquilae		28	21	5	17	Aug. 8	14
(−2	4)	(−2	6)	Aug. 6	18	8	1	24	7
July 5	20	July 4	9	15	15	10	9	δ Cephei	
19	21	18	17	24	12	12	17	(−1	9)
Aug. 2	23	Aug. 2	1	WZ Cygni Minimum		15	1	July 3	6
17	0	16	10	July 1	15	17	9	13	23
31	1	30	18	3	23	19	18	24	17
U Vulpeculae		S Sagittae		6	7	22	2	Aug. 4	10
(−2	3)	(−3	10)					15	4
July 8	7	July 8	4					25	22

Approximate Magnitudes of Variable Stars on May 1, 1906.—

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given have been compiled by Mr. Leon Campbell of the the Harvard College Observatory, from observations made at the Vassar College, Whiteside, and Harvard Observatories.

Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.	Name.	h	R.A. 1900. m	Decl. 1900. ° ′	Magn.
X Androm.	0	10.8	+46 27	14	R Tauri	4	22.8	+ 9 56	14 *d*
T "		17.2	+26 26	13	S "		23.7	+ 9 44	11.3*d*
T Cassiop.		17.2	+55 14	8.7	T Camelop.		30.4	+65 57	9.6*d*
R Androm.		18.8	+38 1	7 *i*	X "		32.6	+74 56	12.7*d*
Y Cephei		31.3	+79 48	12 *d*	V Tauri		46.2	+17 22	10.5*d*
U Cassiop.		40.8	+47 43	14 *d*	V Orionis	5	0.8	+ 3 58	9.0 *i*
V Androm.		44.6	+35 6	11.5*d*	R Aurigae		9.2	+53 28	9.2 *i*
W Cassiop.		49.0	+58 1	12	W "		20.1	+36 49	13.5 *i*
S "	1	12.3	+72 5	12.0 *i*	S "		20.5	+34 4	11.0 *i*
U Persei		52.9	+54 20	8.6 *i*	S Orionis		24.1	− 4 46	8.5 *i*
W Androm.	2	11.2	+43 50	11.5 *i*	S Camelop.		30.2	+68 45	10.5
Z Cephei		13.0	+81 13	12.0*d*	RR Tauri		33.3	+26 19	12.0
S Persei		15.7	+58 8	9.0*d*	U Aurigae		35.6	+31 59	10.0 *i*
RR Cephei		29.4	+80 42	14	V Camelop.		49.4	+74 30	9.8*d*
R Triang.		31.0	+33 50	10.5*d*	U Orionis		49.9	+20 10	7.5 *i*
T Arietis		42.8	+17 6	8.5 *i*	Z Aurigae		53.7	+53 18	10 *i*
W Persei		43.2	+56 34	10.7*d*	X "	6	4.4	+50 14	11.8*d*
Y "	3	20.9	+43 50	9.2	V "		16.5	+47 45	9.0
R "		23.7	+35 20	13.7*d*	V Monoc.		17.7	− 2 9	13.0*d*
Nova Per. No. 2		24.4	+43 34	13 *d*	R "		33.7	+ 8 49	11.5

Approximate Magnitudes of Variable Stars on May 1, 1906.

(Continued.)

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
S Lyncis	6	35.9	+58	0	12.0*d*	R Can. Ven.	13	44.6	+40	2	7.5*d*
X Gemin.		40.7	+30	23	8.8 *i*	Z Bootis	14	1.7	+13	58	13.5*d*
W Monoc.		47.5	− 7	2	11.0	S "		19.5	+54	16	10.5*d*
Y "		51.3	+11	22	10.0 *i*	RS Virginis		22.3	+ 5	8	13.5*d*
X "		52.4	− 8	56	8.0*d*	R Camelop.		25.1	+84	17	12.8*d*
R Lyncis		53.0	+55	28	13.0*d*	V Bootis		25.7	+39	18	9.7 *i*
RS Gemin.		55.2	+30	40	9.8 *i*	R "		32.8	+27	10	10.8*d*
R "	7	1.3	+22	52	13.8*d*	V Librae		34.8	−17	4	12.3*d*
V Can. Min.		1.5	+ 9	1	14	U Bootis		49.7	+18	6	9.8 *i*
R " "		3.0	+10	11	7.7 *i*	RT Librae	15	0.8	−18	21	8.9 *i*
RR Monoc.		12.4	+ 1	17	<14	T "		5.0	−19	38	11.1 *i*
V Gemin.		17.6	+13	7	11.7 *i*	Y "		6.4	− 5	38	8.5 *i*
S Can. Min.		27.3	+ 8	32	11.8*d*	S "		15.6	−20	2	12.3*d*
T Can. Min.		28.4	+11	58	12.6*d*	S Serpentis		17.0	+14	40	12.7
U " "		35.9	+ 8	37	11.3*d*	S Coronae		17.3	+31	44	8.5*d*
S Gemin.		37.0	+23	40	13.5	RS Librae		18.5	−22	33	8.9*d*
T "		43.3	+23	59	9.0 *i*	X "		30.4	−20	50	12.0
U "		49.2	+22	16	14.0	S Urs. Min.		33.4	+78	38	11.5 *i*
R Cancri	8	11.0	+12	2	11.8*d*	U Librae		36.2	−20	52	9.0 *i*
V "		16.0	+17	36	9.5 *i*	Z "		40.7	−20	49	10.8 *i*
RT Hydrae		24.7	− 5	59	7.8 *i*	R Coronae		44.4	+28	28	6.0
U Cancri		30.0	+19	14	13.8	— "		45.3	+37	49	12.6*d*
X Urs. Maj.		33.9	+50	29	9.4*d*	R Serpentis		46.1	+15	26	9.8 *i*
S Hydrae		48.4	+ 3	27	10.8*d*	V Coronæ		46.0	+39	52	8.1 *i*
T "		50.8	− 8	46	9.2 *i*	R Librae		47.9	−15	56	<12
T Cancri		51.0	−20	14	9.0*d*	RZ Scorpii		58.6	−23	50	10.8
W "	9	4.0	+25	39	13.5	R Herc.	16	1.7	+18	38	13.5 *i*
X Hydrae		30.7	−14	15	8.5*d*	Z Scorpii		0.1	−21	28	9.8 *i*
Y Draconis		31.1	+78	13	<13	RR Herculis		1.5	+50	46	9.6*d*
R Leo. Min.		39.6	+34	58	11.6*d*	U Serpentis		2.5	+10	12	9.3 *i*
RR Hydrae		40.4	−23	34	<12	W Scorpii		5.9	−19	53	<12
R Leonis		42.2	+11	54	6.3*d*	RX "		5.9	−24	38	<12
Y Hydrae		46.4	−22	33	7.0	RU Herculis		6.0	+25	20	11.5*d*
V Leonis		54.5	+21	44	12.4*d*	R Scorpii		11.7	−22	42	<12
R Urs. Maj.	10	37.6	+60	18	9.6*d*	S "		11.7	−22	39	12.0*d*
V Hydrae		46.8	−20	43	9.2	W Coronae		11.8	+38	3	12.0*d*
W Leonis		48.4	+14	15	9.0*d*	W Ophiuchi		16.0	− 7	28	<12
S "	11	5.7	+ 6	0	13.6*d*	V "		21.2	−12	12	8.7 *i*
R Comae		59.1	+19	20	13.8 *i*	U Herculis		21.4	+19	17	7.8 *i*
RX Virginis		59.6	− 5	13	7.8 *i*	Y Scorpii		23.8	−19	13	<11
RW "	12	2.1	− 6	12	7.0 *i*	T Ophiuchi		28.0	−15	55	8.8
T "		9.5	− 5	29	12.7*d*	SS Herculis		28.0	+ 7	3	<11
R Corvi		14.4	−18	42	12.7	S Ophiuchi		28.5	−16	57	<11.5
T Can. Ven.		25.2	+32	3	9.8*d*	W Herculis		31.7	+37	2	8.8 *i*
Y Virginis		28.7	− 3	52	14.1*d*	R Draconis		32.4	+66	58	9.5*d*
T Urs. Maj.		31.8	+16	2	13.2	RR Ophiuchi		43.2	−19	17	<12
R Virginis		33.4	+ 7	32	10.3 *i*	S Herculis		47.4	+15	7	7.0 *i*
RS Urs. Maj.		34.4	+59	3	13.5*d*	RV "		56.8	+31	22	14
S " "		39.6	+61	38	8.4*d*	R Ophiuchi	17	2.0	−15	58	8.5 *i*
RU Virginis		42.2	+ 4	22	8.5*d*	Z "		14.5	+ 1	37	<11
U "		46.0	+ 6	6	11.8*d*	RS Herculis		17.5	+23	1	8.8*d*
RT "		57.6	+ 5	43	7.7 *i*	RS Ophiuchi		44.8	− 6	40	10.5
RV "	13	2.7	−12	38	14	RY Herculis		55.4	+19	29	11.5
V "		22.6	− 2	39	12.8*d*	V Draconis		56.3	+54	53	<12
R Hydrae		24.2	−22	46	5.6 *i*	RW Herculis	18	1.7	+22	4	<11.5
S Virginis		27.8	− 6	41	12.5*d*	W Draconis		5.4	+65	56	<10
T Urs. Min.		32.6	+73	57	10.5*d*	T Herculis		5.3	+31	0	11.9*d*

Approximate Magnitudes of Variable Stars on May 1, 1906.

(Continued)

Name.	R. A. 1900 h m	Decl. 1900 ° ′	Magn.	Name.	R.A. 1900 h m	Decl 1900 ° ′	Magn.
X Draconis 18	6.8	+66 8	<11.5	Z Cygni 19	58.6	+49 46	13.5
W Lyrae	11.5	+36 38	10.0 *i*	S Aquilae 20	3.4	+57 42	11.0
T Serpentis	23.9	+ 6 14	9.2 *i*	RS Cygni	9.8	+38 28	8.0*d*
X Ophiuchi	33.6	+ 8 44	7.2 i	R Delphini	10.1	+ 8 47	11.8*d*
RY Lyrae	41.2	+34 34	12.0*d*	SX Cygni	11.6	+30 46	9.8
R Scuti	42.2	− 5 49	4.8	U "	16.5	+47 35	10.0
RX Lyrae	50.4	+32 42	<12	RW "	25.2	+39 39	8.0 *i*
R Aquilae 19	1.6	+ 8 5	8.0 *i*	Z Delphini	28.1	+17 6	8.5 *i*
V Lyrae	5.2	+29 30	12.5*d*	Y "	36.8	+11 30	<12
RX Sagittarii	8.7	+18 59	11.5	S "	38.5	+16 44	10.5
RW "	8.1	−19 2	9.0	T "	40.7	+16 2	<12
S Lyrae	9.1	+25 50	<12	V "	43.2	+18 58	<12
RS "	9.3	+33 15	10.0 *i*	X "	50.3	+17 16	<12
R Sagittarii	10.8	−19 29	7.2	— "	50.3	+17 18	9.0 *i*
S "	13.6	−19 12	<11.5	R Vulpeculae	59.9	+23 26	11.8*d*
U Lyrae	16.6	+37 42	<12	T Cephei 21	8.2	+68 5	6.6 *i*
T Sagittae	17.2	+17 28	9.6	S "	36.5	+78 10	10.2 *i*
TY Cygni	29.8	+28 6	<12	SS Cygni	38.8	+43 8	8.5*d*
RT Aquilae	33.3	+11 29	<12	RT Pegasi	59.8	+34 38	<11.5
R Cygni	34.1	+49 58	8.6*d*	T Lacertae 22	17.9	+33 52	9.5
RV Aquilae	35.9	+ 9 42	<11.5	S "	24.6	+39 48	9.8 *i*
RT Cygni	40.8	+48 32	8.5 *i*	R "	38.8	+41 51	11.5*d*
X Aquilae	46.5	+ 4 12	<12	Z Cassiop.	39.7	+56 2	11.5 *i*
χ Cygni	46.7	+32 40	8.9*d*	R "	53.3	+50 50	11.0 *i*

GENERAL NOTES.

The Recent California Earthquake. Considerable anxiety was felt, in astronomical circles for the observatories of California when it was first known what great damage had come to life and property in a wide district of the state in view of that terrible earthquake. It was soon learned, however, that the observatories and their instruments all escaped unharmed.

The circumstances of such unusual phenomena are always interesting. Under date of April 26, our esteemed correspondent, Miss O'Halloran, in a private letter writes as follows:

"The western part of San Francisco, where I live, was but little damaged by the earthquake. It occurred some minutes before sunrise. I arose immediately to save my four-inch refractor from falling, but before I reached it, the tripod fell over towards me and I caught it just in time. Had it fallen in any other direction the lens which was eight feet from the ground would have been shattered.

Before two hours, I sketched the few spots on the Sun's surface, which was rather serene as it shone for the first time over the crumbling ruins. San Francisco is sublime in its hope and courage."

From Lick Observatory, Mount Hamilton, R. H. Tucker writes:

"We were very fortunate in not having any damage done by the earthquake; and no one hurt.

The worst shock undoubtedly occurred in the valley near Palo Alto, on the south of San Francisco: and at Santa Rosa as far north. There was little or no vertical vibration, no jolt, such as we may experience in slight ones often. We appreciate the great interest every one exhibits in the welfare of the Observatory."

Notice. If there are any American astronomers who would like to compute one or more orbits for new asteroids the undersigned would be glad to hear from them.

JOEL H. METCALF.

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Taunton, Mass.

New York Observatory and Nautical Museum. Since writing the brief article about preliminary steps taken to build an Observatory and Nautical Museum in the city of New York, elsewhere printed in this number, further information comes to hand indicating that the planning is going forward with such promise of completion in the near future as to be very encouraging to its immediate friends, as well as very gratifying to the wider circles of science always interested in steps of substantial progress.

When the great men in financial circles of New York unitedly start to do something this country and the world have learned to expect large results soon to follow. We have just learned, at this date (May 10) that the day following the meeting in the first week of May, a large part of the $500,000 endowment for this new enterprise had been raised. This working committee includes the names of Frederick G. Bourne, Cornelius Vanderbilt, Edward S. Isham, George A. Cormack and Charles Lane Poor. The plan is to build somewhere in Bronx, a museum, where models of all types of vessels and nautical instruments may be exhibited, and an Observatory where scientific investigations in the field of Astronomy, Navigation and kindred subjects may be carried on.

In the *New York Sun* of May 4 was given a full notice of this important recent movement in New York, in the interest of science, with the added fact that prominent men interested would urge Mayor McClellan to use his influence to insure the success of this new project.

POPULAR ASTRONOMY heartily congratulates Professor Poor and others interested from the Astronomical Department of Columbia University on the bright prospect before them in the interest of Astronomy, the noblest of all the sciences.

Crommelin's Communication to *Popular Astronomy*. "May I trespass further on your courtesy for a little space to reply to the letter of Professors Campbell and Perrine in the April number of POPULAR ASTRONOMY?

In my previous letter I had forgotten the exact dates of publication of my own paper on Phoebe, and of Professor W. H. Pickering's Memoir on the subject; I have since then examined the point, and find that the number of *Astronomische Nachrichten* containing my paper was closed for press 1904 October 14, and published three or four days later. Professor Pickering's Memoir arrived at Greenwich 1904 October 15 as is shown by the official stamp upon it. In other words the Memoir was in Europe two days before the publication of my paper. Thus Professors Campbell's and Perrine's words on page 137 of POPULAR ASTRONOMY, "to publish the most interesting fact concerning its orbit, *in advance* of the discoverer's publication" is not accurate, and I think that they will admit that their case is considerably modified. It is true that a paragraph in the *Observatory* published about 1904 October 3, contained a "conjecture" by me that the orbit might be retrograde, but so doubtfully expressed that this can hardly be regarded as definite publication. Even my paper in the *Astronomische Nachrichten* was so tentative, and based on such slender material, that the few astronomers who read it before they read the Memoir would only turn to the latter with greater eagerness and zest, just as Hors d' Oeuvres at a banquet are

supposed to increase one's relish for the more satisfying food which follows.

As regards the "astronomical value" of my paper, my estimate of this is extremely small; but such as it is, it depends upon the entire independence of my determination of retrograde motion; it would have no weight at all in this respect unless it had left my hands before I saw the Memoir.

On the point that "controversy of this sort is most unfortunate," I cordially agree with Professors Campbell and Perrine, but I do not understand how my criticisms on an entirely different subject (which I do not admit were in "strong language") can be said to have "forced" them to intervene in this one, with which they were in no way connected."

ANDREW C. D. CROMMELIN.

35 Ulundi Road,
Blackheath, London.

Maxima of Long Period Variables. The maxima of the following long period variables were determined from the single light curves obtained from observations made at Vassar College with a five-inch telescope. Argelander's method of sequences was used in estimating magnitude. The comparison stars were obtained from the Hagen maps with the exception of those for RT Cygni and V Cassiopeiæ which were taken from the Bonner Durchmusterung. Chandler's Ephemerides of Long Period Variables gave the predicted maxima.

243 U Cassiopeiæ.

Date.	Magnitude.
Oct. 4, 1905.	<10.8
" 26	<10.2
Nov. 18	9.6
Dec. 12	8.0
" 26	8.0
Jan. 9, 1906.	8.2
" 24	8.4
Feb. 13	9.4
" 23	9.6

Maximum, 8.0 magnitude, on Dec. 25, 1905.
Predicted maximum, Nov. 3, 1905.

782 R Arietis.

Date.	Magnitude.
Nov. 3, 1905.	10.8.
" 21	9.6
" 30	9.5
Dec. 7	9.9
" 13	9.2
" 26	8.6
Jan. 9, 1906.	8.7
" 24	9.5
Feb. 13	9.5
Mar. 6	10.0

Maximum, 8.7 magnitude, on Dec. 26.
Predicted maximum, Dec. 26.

906 R Trianguli.

Date.	Magnitude.
Nov. 2, 1905.	9.4
" 3	9.4
" 21	8.7
Dec. 26	7.6
Jan. 9, 1906.	7.8
" 24	7.6
Feb. 6	7.0

Maximum 7.2 magnitude, on Jan. 28, 1906.
Predicted maximum, Feb. 6, 1906.

1577 R Tauri.

Date.	Magnitude.
Nov. 21, 1905.	9.3
" 25	10.5
Dec. 7	9.6
Jan. 16, 1906.	11.3
" 17	11.3

That maximum was passed before the first observation is here indicated.
Predicted maximum was Dec. 7, 1905.

7085 RT Cygni.

Date.	Magnitude.
Oct. 10, 1905.	9.0
" 17	8.4
" 26	7.9
Nov. 18	7.2
" 20	7.3
" 21	7.3
" 25	7.3
Dec. 7	7.4
" 13	7.6

Maximum was 7.2 magnitude on Nov. 24, 1905.
Predicted maximum was on Dec 1, 1905.

8324 V Cassiopeiæ.

Date.	Magnitude.
Oct. 17, 1905.	8.4
" 26	8.6
Nov. 18	8.0
" 20	8.6
" 21	8.7
" 25	9.7
Dec. 12	9.0
Jan. 24, 1906.	9.1
Feb. 6	9.0
Mar. 6	9.0

Maximum was 8.4 magnitude on Nov 10, 1905.
Predicted maximum was Dec. 7, 1905.

Vassar College, April 20, 1906.

RUTH E. SMITH, AND
GRETA SIMPSON.

Franklin as a Man of Science is the subject of an elaborate address by Dr. Edwin J. Houston, Emeritus Professor of Physics, Franklin Institute, Philadelphia. It covers 147 pages in the April and May numbers of the *Journal of the Franklin Institute*.

Greenwich Publications. A valuable collection of the Greenwich Publications has just been received. They are:

1. New Reduction of Groombridges Circumpolar Catalogue for the Epoch of 1810.0
2. Greenwich Astronomical Results for 1903; largely transit-circle work.
3. Determinations of Longitude, by the telegraphic method made between 1888 and 1902.
4. Micrometrical Measurements of Double-Stars by Innes at the Observatory of the Cape of Good Hope under the direction of Sir David Gill.
5. Magnetic and Meteorological Observations for 1903.
6. Greenwich Clock Star List for 1906.

Measurements of Minute Linear Distances. From that splendid address made by Ambrose Swasey in 1904 on Some Refinements of Mechanical Science we quote the following:—

In the realm of the measurements of minute linear distances, and the perfection of curved and flat surfaces, the refinements are even greater than those pertaining to the measurement of time and of angles.

Most important in the linear dividing engine is the screw, and although much had been accomplished in bringing such engines to a high degree of excellence, it was for Professor Rowland to make an engine which has a practically perfect screw, and without doubt it is in all respects the nearest perfect of all the mechanisms that have been employed for ruling lines exactly parallel and equally spaced.

The Rowland engine was made especially for ruling diffraction gratings which are made of speculum metal, and with it a metal surface has been ruled with 160,000 lines, there being about 29,000 to the inch, and as many as 43,000 lines to the inch have been ruled.

The gratings mostly used have from 14,000 to 20,000 lines to the inch, and with such exactness is the cutting tool moved by the screw that the greatest error in the ruling does not exceed one millionth of an inch.

The production of these gratings which has enabled the physicist in his study of the spectrum to enter fields of research before unknown, has not only called for the highest degree of perfection ever attained in the spacing of linear distances, but it has also called for a refinement most difficult in the optical surfaces upon which the lines are ruled. To Mr. Brashear was given the problem of producing such surfaces, and notwithstanding the many difficulties encountered in working and refining the speculum metal plates, he has made many hundred plates with surfaces either flat or curved with an error not to exceed one tenth of a wave length of light, or one four-hundred-thousandth of an inch.

As the established standards of length which are the yard of Great Britain and the meter of France, are made of metal, and liable to destruction or damage, Professor Michelson conceived the idea of determining the lengths of these standards in wave lengths of light, which would be a basis of value unalterable and indestructible.

For the purpose of carrying out these experiments the interferometer was constructed, an instrument which required the highest order of workmanship and the greatest skill of the optician. Again Mr. Brashear proved to be equal to the occasion, and made for the instrument a series of refracting plates, the surfaces of which were flat within one twentieth of a wave length of light, with sides parallel within one second. This was the most difficult work ever attempted in the refinement of optical surfaces.

Professors Michelson and Morley devised a method for using the interferometer to make the wave length of some definite light an actual and practical standard of length. So satisfactory was the result that Professor Michelson was invited to continue the experiments at the Bureau of Weights and Measures, at Sèvres, France, where the standard meter, which is kept in an underground vault and inspected only at long intervals, was used for that important work. The final result of the experiments, which occupied nearly a year, shows that there are 1,553,164.5 wave lengths of red cadmium light in the French standard meter, at 15 degrees Centigrade. So great is the accuracy of these experiments, that they can be repeated within one part in two millions. Should the material standard of length be damaged or destroyed, the standard wave length of light will remain unaltered as a basis from which an exact duplicate of the original standard can be made. These two marvelous instruments, the Rowland dividing engine and the Michelson interferometer, show the possibilities in the perfection of linear divisions and the standards of length.

We have recounted some steps of the progress that has been made in the measurement of time, of angles, and of length, together with some of the refinements in these measurements, but we are confronted with the fact that notwithstanding all that has been accomplished from centuries past down to the present time, there are, as ever before, many imperfections requiring new problems in mechanical science to be worked out for the further enlightenment and welfare of mankind.

Professor H. H. Turner, Savilian Professor at Oxford University and Director of the Radcliffe Observatory has kindly remembered us with many of his recent papers that deal mostly with the hard problems in Astronomy at the present time. Speaking of his recent visit to America he said, while here, "opportunity was taken to visit the Harvard, Albany, Yerkes, Lowell, Mount Wilson and Lick Observatories, with the greatest profit and pleasure. Astronomy has gone ahead so fast in the United States that there is a great deal to learn from such a visit."

Useful Papers from Various Sources. From the Observatory in Stockholm and other Swedish sources we have received more than a score of interesting papers on themes relating to modern Astronomy. C. V. L. Charlier is the author of many of them.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

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Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

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Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with the Jannary number the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, Canada and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers are still on sale at the old prices, $2.50 and 30 cents, respectively.

WM. W. PAYNE,
Northfield, Minn., U. S A.